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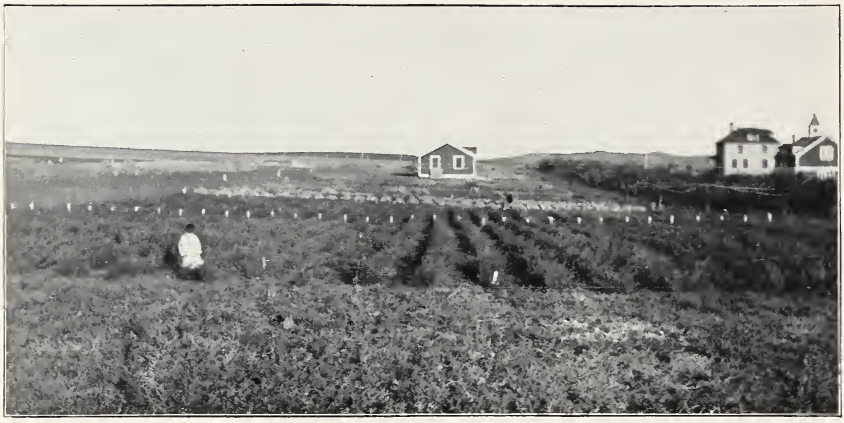

FIG. 1.—EXPERIMENTAL PLATS OF ALFALFA IN HILLS AND DRILL ROWS AT DICKINSON, N. DAK., OCTOBER 1, 1908.

Each row is seeded with a different strain, 68 kinds in all.

FIG. 2.—THE SAME EXPERIMENTAL PLATS ILLUSTRATED IN FIGURE 1 ON JUNE 10, 1909, SHOWING THE GREAT DIVERSITY IN THE WINTER RESISTANCE OF ALFALFA FROM DIFFERENT PARTS OF THE WORLD.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 185.

B. T. GALLOWAY, *Chief of Bureau.*

COLD RESISTANCE OF ALFALFA AND SOME FACTORS INFLUENCING IT.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 6, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Cold Resistance of Alfalfa and Some Factors Influencing It." This report was prepared by Mr. Charles J. Brand while Physiologist in Charge of Clover and Alfalfa Investigations in the Office of Crop Physiology and Breeding Investigations, and by Mr. L. R. Waldron, superintendent of the subexperiment station conducted by the State of North Dakota at Dickinson. I recommend that it be published as Bulletin No. 185 of the special series of this Bureau.

One of the important lines of investigation in the Bureau of Plant Industry is the determination of the factors that make it possible for plants to thrive in the extremely cold sections of the West and Northwest. It is a broad, complicated question, and all of the factors can be determined only by studies that extend through many winters of extreme cold. One such season, the winter of 1908–9, occurred during the progress of the studies of the writers and forms the basis of the principal part of the discussion. The investigations reported, however, have been in progress for five years in different parts of the Northwest. They include 80 different kinds of alfalfa, many of which are introductions of this Bureau.

It would have been desirable for the observations of the writers to have extended over a greater number of severe winters. The need of information on the part of those in the cold regions is so pressing, however, that it seems advisable to present the facts contained in the paper as a contribution to the comprehensive series of similar studies in progress in the Bureau. The deductions of the writers are especially helpful in suggesting lines of investigation that are likely to be developed further by investigators in the cold regions, as well as by those within the Bureau. Another phase of alfalfa hardiness has already been discussed in Bulletin No. 169 of this Bureau, entitled "Variegated Alfalfa," by Mr. J. M. Westgate.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—579.

COLD RESISTANCE OF ALFALFA AND SOME FACTORS INFLUENCING IT.

INTRODUCTION.

Interest in the culture of alfalfa continues to increase. As a wealth producer this crop is winning for itself a predominant place in the agriculture of the world. While in some parts of Europe it can no longer be grown with the old-time success, and serious people are discussing measures for bringing its culture back to a paying basis, the United States has as yet developed only a small fraction of its alfalfa possibilities.

So far as the northern part of the Great Plains area is concerned the investigations reported upon in the present paper show that weather, tillage, and the use of a suitable strain of seed are the controlling factors in successful alfalfa production when soils of average fertility are employed. Snow covering and the presence or absence of excess moisture in the soil were found to be fully as important in winterkilling as minimum temperatures; differences in tillage and in the previous treatment of the land had profound effects, and finally the greatest possible diversity was found in the endurance shown by strains of seed from different parts of the world.

PURPOSE OF THE INVESTIGATIONS.

In the autumn of 1904 the Bureau of Plant Industry began a comprehensive study of the alfalfa plant. During the preceding years many new strains had been introduced[a] with a view to finding

[a] During the period that elapsed from May, 1898, until November, 1904, the Office of Foreign Seed and Plant Introduction of the Department of Agriculture introduced a total of forty-two strains of alfalfa from different parts of the world. Included among these earlier importations were the following: Fifteen numbers secured by Professor Hansen in Turkestan which constituted what was, so far as we know, the original introduction into North America of the form of alfalfa grown in that country; four numbers sent in by Mr. Swingle, including the well-known Provence and Poitou strains, also what was probably the Department's first introduction of the so-called commercial sand lucern, from France, and the highly prized Oasis alfalfa of the Sahara from the Oued Rirh; three interesting Algerian strains grown in the province of Constantine, secured by Messrs. Fairchild and Scofield, including the interesting form

better kinds for our older alfalfa-producing areas and also sorts that would succeed in areas where the ordinary strain had failed to establish itself.

Little was known as to how these new plant immigrants would behave in their new surroundings, and as their number grew it became very apparent that there was acute need for information as to what factors governed their successful growth. Without this knowledge the most effective distribution in this country was impossible; hence the investigations begun in 1904 were planned with a view to satisfying this need.

The many forms of alfalfa secured by the Bureau of Plant Industry have now been grown or are being grown in groups of from 2 to more than 200 in several hundred places scattered over the country. These different localities represent in a very full measure the great diversity of climate and soil present in the United States and furnish an opportunity for studying and comparing the behavior of the various kinds of alfalfa under a great range of conditions.

Throughout the southwestern portion of the United States and in practically all areas where irrigation is practiced farmers have had very little difficulty in securing and maintaining highly profitable stands of alfalfa, but up to the present time Kansas and Nebraska are the only States that have made a notable success in growing this crop without irrigation. The alfalfa, or lucern,[a] grown in these States

grown in rows by Mr. G. Ryf, of Setif (see Fairchild, Bulletin 72, pt. 1, Bureau of Plant Industry, U. S. Dept. of Agriculture), a sample of the so-called sand lucern, and the variety known to botanists as *Medicago sativa gaetula*; two numbers from Peru, two from Argentina, and two from Arabia, secured by Messrs. Lathrop and Fairchild; one from Egypt, from Mr. Fairchild; two numbers constituting a new introduction of the Oasis alfalfa, sent by Mr. Kearney from the Oasis of Tuggurt in Algeria; seven new lots from various parts of Turkestan, secured by Mr. Bessey; a commercial importation from Turkestan; two strains from Mexico, and the interesting Peruvian alfalfa described in Bulletin 118 of this Bureau (see Brand, "Peruvian Alfalfa," Bulletin 118, Bureau of Plant Industry, U. S. Dept. of Agriculture).

Since the autumn of 1904 nearly two hundred numbers have been introduced from various parts of the world; in addition a large number of more or less distinct strains have been secured from various parts of the United States, and a still larger number have been secured by propagation of seed from previous introductions. All of these domestic and foreign races and their progeny constitute the richest material for the study and breeding of alfalfa that has ever been brought together.

[a] Alfalfa and lucern are wholly synonymous common names for *Medica sativa* (L.) Mill. [See Scofield, Carl S., "The Botanical History and Classification of Alfalfa," Bulletin 131, pt. 2, Bureau of Plant Industry, U. S. Dept. of Agriculture.] The former is used in practically all Spanish-speaking countries and countries that drew their original supplies of seed directly or indirectly from Spain. This includes nearly all of the western continent. The name "lucern," on the other hand, is the name generally applied in Germany, France, and contiguous countries. It is also the name commonly used by the Mormon farmers of Utah. The common name used in Italy is "herba medica."

came from California and Utah and is probably descended from the Chilean alfalfa introduced into this country about 1855. In a little more than a half century, so readily adaptable is alfalfa, this strain has spread over the agricultural areas of the greater portion of the western half of the United States, where it constitutes the backbone of agriculture. This strain, in the form to which it was unconsciously modified as it moved eastward, has been found hardy in Colorado, Kansas, Wyoming, south of the middle line of Nebraska, and by continued growth has been extended throughout Nebraska and in Montana as far north as the valley of the Milk River in the northern part of the State.

In Kansas, farmers who have been growing alfalfa for from twenty to twenty-five years state that the sort they have used has never winterkilled to a noticeable extent.

Speaking broadly, there are three great areas for which no well-adapted alfalfa has been available in quantity: (1) The humid Eastern and Southern States; (2) the semiarid regions where irrigation water is not available, including especially the drier parts of the Great Plains and Intermountain areas, and (3) the cold northern part of the country.

In the region north of the Valley of the Platte in Nebraska and extending eastward to the Atlantic Ocean none of the strains of alfalfa, either of Chilean or European origin, obtainable in commercial quantities have proved hardy in the sense that they can be absolutely depended upon. Hence, one of the great needs of our northern agriculture and that of Canada has been an alfalfa that is perfectly hardy and reliable in this area.

It is the purpose of the present paper to discuss rather fully some of the factors that appear to be important in the wintering over and winterkilling of alfalfa. The greater part of this work has been done in North Dakota at the Dickinson subexperiment station, but advantage has also been taken of using, for collateral observations, numerous other experiments located in various parts of the West, North, and Northwest.

Dickinson is located in the western part of North Dakota at an altitude of 2,453 feet. The range of temperature thus far recorded is from $-47°$ to 110° F. The winters are severe on plant life. The soil is similar to that of much of the Great Plains area. An alfalfa that does well at Dickinson is likely to succeed in a large part of the surrounding region.

EXPERIMENTS AT DICKINSON, N. DAK., BEGUN IN 1906.

With a view to gaining some knowledge as to their comparative cold resistance and also to determine the factors affecting cold resistance in various strains under moderately light rainfall, a series of

22 strains of alfalfa (see Table I) was sown in duplicate on plats one-fortieth of an acre each in the spring of 1906. One complete set was sown on the best soil on the experiment farm, a rich sandy loam, while the duplicate series was placed on a light sandy piece of land on another part of the farm. The series on sandy soil was sown May 9, 1906; that on the loam May 10.

The following table shows the serial number, the region of origin, and the estimated percentage of stand on both the sand and the loam during the first or seeding year and the percentage of stand remaining after the severe winter of 1906–7.

TABLE I.—*Results of experiments with different strains of alfalfa grown on sandy soil and on loam at Dickinson, N. Dak., during 1906 and 1907, showing the percentage of a perfect stand which survived the winters.*

No.	Origin.	Sandy soil.				Loam.			
		1906.		1907.		1906.		1907.	
		Stand.	Date.	Stand.	Date.	Stand.	Date.	Stand.	Date.
		Per ct.		*Per ct.*		*Per ct.*		*Per ct.*	
[a] D. E. S. 223	Fargo, N. Dak. (Grimm, crop of 1904).	80	Aug. 15	80	June 3	95	Aug. 1	95	June 3
D. E. S. 241	Gladstone, N Dak. (crop of 1905).[b]	.....	.....	.....	.....	95	...do....	65	Do.
D. E. S. 282	Commercial alfalfa.[b]	70	Aug. 15	10	June 3	.....	.....	.....	.....
[a] S. P. I. 9303	Peru.....	10	...do....	1	...do....	40	Aug. 1	5	June 3
S. P. I. 12694	Provence, France	75	...do....	4	...do....	85	...do....	40	Do.
S. P. I. 11211	Commercial Turkestan.	80	...do....	75	...do....	85	...do....	85	Do.
S. P. I. 12398	Colorado.....	80	...do....	15	...do....	90	...do....	60	Do
S. P. I. 17449	Commercial American.	75	...do....	12	...do....	93	...do....	50	Do.
S. P. I. 12747	Yellowstone Valley, Mont.	75	...do....	20	...do....	90	...do....	65	Do.
S. P. I. 13291	Fayetteville, N. Y.	75	...do....	50	...do....	90	...do....	65	Do.
S. P. I. 12784	Utah (irrigated).	70	...do....	5	...do....	90	...do....	50	Do.
S. P. I. 12816	Milk River Valley, Mont.	75	...do....	15	...do....	80	...do....	55	Do.
S. P. I. 12801	Texas Panhandle.	75	...do....	5	...do....	80	...do....	40	Do.
S. P. I. 13259	Southern Nebraska.	60	...do....	25	...do....	80	...do....	65	Do.
S. P. I. 13237	Chinook, Mont..	75	...do....	4	...do....	85	...do....	55	Do.
S. P. I. 12671	Kansas.....	75	...do....	40	...do....	85	...do....	60	Do.
S. P. I. 12820	Northern Nebraska.	70	...do....	45	...do....	90	...do....	65	Do.
S. P. I. 12748	Rhine Province, Germany.	75	...do....	45	...do....	85	...do....	35	Do.
S. P. I. 14786	Tashkend, Turkestan.	85	...do....	85	...do....	85	...do....	85	Do.
S. P. I. 12409	Utah (not irrigated).	75	...do....	20	...do....	85	...do....	20	Do.
S. P. I. 13858	Kharkof, Russia.	90	...do....	25	...do....	95	...do....	80	Do.
S. P. I. 13857	Simbirsk, Russia	60	...do....	55	...do....	70	...do....	60	Do.
	Average...	72.7	.....	29	.....	84.6	.....	56.1	.....

[a] These abbreviations refer to the serial numbers of the Dickinson subexperiment station and of the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry.
[b] These strains were not in duplicate.

It will be noted that the stand on the loam is in nearly every case better than that on the sand and that the loss in stand observed in

1907 as compared with 1906 is practically always greater on the sandy soil than on the loam. Although this loss in stand is undoubtedly due in large part to winterkilling, it is no doubt true that a part of it may be accounted for by the fact that the sandy soil is much less retentive of moisture than the loam, so that the deterioration of the stand on the sandy soil would be due to a combination of drought and cold. The likelihood of this will be more apparent after reading the discussion of the precipitation of the autumn of 1906 given below.

RAINFALL.

The rainfall during 1906 was 19.99 inches, while the yearly average based on a 16-year record is 15.11 inches. Despite the fact that the precipitation exceeded the average considerably, there were times during 1906 and 1907, as may be judged from the following table (Table II), when a lack of moisture interfered notably with the growth of the crop. This was particularly true during July, 1906. The dry spell that occurred in this month was in part responsible for the small growth made on all plats during the season of 1906. The most important factor in contributing to the lack of vigorous growth was the failure to secure inoculation. The effect of inoculation on cold resistance will be more fully discussed later.

TABLE II.—*Rainfall in inches at Dickinson, N. Dak., for 1906, 1907, and 1908.*[a]

	Average for 16 years.	1906.	1907.	1908.
January	0.39	0.25	0.80	0.28
February	.48	.32	.14	.73
March	.99	.98	.39	1.42
April	1.18	1.10	.30	1.27
May	2.43	7.11	1.36	3.50
June	2.92	5.40	2.52	4.30
July	2.12	.16	4.82	1.41
August	1.82	2.64	1.89	1.43
September	1.04	.25	1.11	1.67
October	.70	.14	.10	2.47
November	.56	.87	.02	.78
December	.48	.77	.22	.24
Annual	15.11	19.99	13.67	19.50

[a] This table is quoted from Waldron, L. R., First Annual Report of the Dickinson Sub-Experiment Station for the year 1908, Fargo, N. Dak., 1909.

TEMPERATURE.

The winter of 1906–7 was one of extraordinary severity. The minimum temperature for October was 11° F.; November, −1° F.; December, −24° F.; January, −35° F.; February, −31° F.; March, −8° F.; and April, 5° F. During January there were only two days when the minimum temperature registered was above zero (3° F. on January 1 and 5° F. on January 11) and only one day when the maximum rose above freezing (35° F. on January 23).

In order to show more adequately the nature of the weather which the experimental alfalfas shown in Table I were called upon to endure the report of the Weather Bureau for the month of January, 1907, is presented in its entirety in Table III.

TABLE III.—*Daily record of temperature and precipitation for the month of January, 1907, at Dickinson, N. Dak.; latitude, 46° 50′ N.; longitude, 102° 50′ W.; altitude, 2,453 feet.*

Date.	Temperature.				Precipitation.		MONTHLY SUMMARY.
	Maximum.	Minimum.	Range.	Record at 6 p. m.	Snowfall.	Depth of snow on ground at time of observation.	
	° F.	° F.	° F.	° F.	*Inches.*	*Inches.*	*Temperature.*
1	5	3	2	4	1	7.5	Mean maximum, 5.93° F.
2	− 1	− 8	7	− 8	1	8.5	Mean minimum, −13.74° F.
3	− 1	−20	19	− 3	.....	.....	Mean, −3.9° F.
4	6	− 4	10	2	.....	.....	Maximum, 35° F.; date, 23d.
5	− 2	− 5	3	− 3	.....	.....	Minimum, −35° F.; date, 15th.
6	5	− 4	9	3	.....	.....	Greatest daily range, 38° F.
7	6	− 7	13	− 3	[a] T.	.....	
8	− 8	−14	6	−14	.....	.....	*Snow.*
9	14	−23	35	−12	.....	.....	Total fall, 8 inches.
10	9	−22	13	15	.....	.....	
11	15	5	10	5	3	11.5	REMARKS.
12	5	−13	18	−11	[a] T.	.....	Temperature, 15.1° F. below normal.
13	− 6	−14	8	− 9	1	12.5	
14	−23	−33	10	−29	.....	.....	
15	−13	−35	22	−13	.....	.....	
16	− 9	−16	7	−14	1	13.5	
17	11	−22	33	− 6	.....	.....	
18	23	−16	39	14	.....	.....	
19	24	−14	38	−14	.....	.....	
20	0	−28	28	0	.....	.....	
21	24	− 3	27	− 3	.....	.....	
22	12	−13	25	11	.....	.....	
23	35	− 3	38	24	.....	.....	
24	30	− 6	36	− 2	.....	.....	
25	− 1	−15	14	− 1	.....	.....	
26	4	−13	17	− 5	.....	.....	
27	− 4	−20	16	−20	.....	.....	
28	− 7	−21	14	−12	1	14.5	
29	− 6	−25	19	−12	.....	.....	
30	7	−17	24	3	.....	.....	
31	30	− 2	32	22	.....	.....	
Sum	184	−428	.....	.....	.....	.....	
Mean	5.9	−13.8	.....	.....	.....	.....	

[a] T.=trace.

An examination of the columns of Table I showing the stand for 1907 reveals the fact that some plants on every plat in both series survived the winter. In several cases the strains came through with no injury whatever, and even the plats of the Peruvian variety, which next to the Arabian is perhaps the least hardy alfalfa known, had a sprinkling of living plants amounting on the sandy soil to about 1 per cent of a stand and on the loam to about 5 per cent.

REASONS WHY ALFALFAS SURVIVED THE WINTER OF 1906–7.

It is surprising, in view of the severity of the winter of 1906–7, which was almost unprecedented in North Dakota, that so large a percentage of alfalfa plants survived. From a careful study of the weather records for Dickinson from September, 1906, to May, 1907, inclusive, it seems that two factors were largely concerned in the result, namely, autumn weather of a kind that induced comparative dormancy before the real winter weather came, and a heavy blanket of snow throughout the coldest winter months.

Beginning with September 10 there was on the whole a gradual downward movement of the mean daily temperature, which culminated in killing frosts on the 26th and again on the 29th of the month. This and the dryness of the soil, the precipitation for the whole month being only 0.25 of an inch, served to harden the tissues of the plant and inhibit the production of new and tender growth.

In October a very similar condition of affairs obtained. A precipitation of only 0.14 of an inch for the whole month was recorded. The temperature went down rather gradually, with killing frosts on the 5th, 9th, and 10th, while from the 18th to the 31st of October the daily minimum temperature ranged from 37° to 11° F., only two days (37° F. on the 25th and 35° F. on the 26th) having minima above the freezing point.

The result of this combination of dryness and gradually increasing cold was first to bring about a gradual cessation of the physiological processes involved in growth, and finally to bring the plants unharmed into a comparatively dormant condition.

Several years of observation have led to the conclusion that a capacity to react with reasonable promptness to stimuli producing dormancy is one of the most important qualities, if not the most important, in producing hardiness in alfalfas and clovers. Similarly during dormancy, resistance to growth-producing stimuli is important.

Elsewhere[a] an attempt has been made to explain the failure of one variety to become dormant while another becomes so, by conceiving varieties and even individuals as having a more or less constant minimum temperature, below which growth ceases in the autumn and above which it starts in the spring. Breeders desiring to establish races for particular purposes should seek wherever possible to correlate one physiological character with another rather than morphological characters with physiological, unless there is a fairly obvious relation between the physical character used as a basis of judgment and the physiological character toward which selection is

[a] Brand, Charles J. Peruvian Alfalfa: A New Long-Season Variety for the Southwest. Bulletin 118, Bureau of Plant Industry, U. S. Dept. of Agriculture, pp. 8–14.

being made. That dormancy is of paramount importance in determining whether alfalfas will winterkill or not appears to be shown by the results of 1906 and 1907 as compared with those of 1908 and 1909, given later.

No two conditions are more potent than drought and cold in retarding plant growth or bringing it to a complete standstill by hardening the tissues.

Both temperature and moisture conditions were ideal in western North Dakota during the autumn of 1906 for bringing about this result. Those for September and October have already been described.

November weather was generally favorable for inducing dormancy, and a snow covering was present during a portion of the month. The total precipitation for the month amounted to 0.87 inch, of which 0.22 inch fell before the middle of the month and had a good chance to become absorbed by the soil. Only a portion of this soaked in. The remainder of the precipitation was in the form of snow, which remained until the end of the month.

The precipitation for December was above the normal, but nearly all of this came in the form of snow, which remained in place. A short period of warm weather at the beginning of the month removed the snow, but on the 9th and 13th more snow fell, forming a covering over 7 inches deep. The temperature for December was 4.1° F. below the normal. The minimum temperatures ranged from 28° to −24° F., while the maxima ranged from 47° to −1° F. The snow afforded the plants a high degree of protection.

The weather conditions during January, 1907, are shown in Table III and discussed in that connection. Attention here is directed only to the snowfall. The month opened with 7.5 inches (see Table III) on the ground; on the 15th there were 12.5 inches, and at the end of the month there were 14.5 inches. Without this blanket of snow and with the persistently low temperatures that occurred throughout the month it is probable that there would have been 100 per cent of winterkilling on the majority of the experimental plats, and this despite the extremely favorable conditions under which the alfalfa entered the winter. As it was, red clover, winter wheat, and some alfalfa on every one of the twenty-two plats survived the winter.

As is always the case in this northern region, the weather during February, 1907, was also severe, the mean of the minimum temperature being 4° F. and the absolute minimum −31° F. The month began with 14.5 inches of snow on the ground, 6 inches remaining on the 15th and 4 inches at the end.

In order to make possible a comparison of mean temperatures endured by the alfalfas under experiment during the winter of 1906–7

with those endured by the strains under experiment during 1908–9, the mean temperatures for these years are shown in the following table:

TABLE IV.—*Mean temperatures for Dickinson,[a] N. Dak., during 1906, 1907, 1908, and 1909, the years covered by the alfalfa experiments reported upon in this bulletin.*

Month.	Average for 16 years.[b]	1906.			1907.			1908.			1909.		
		Mean of the maxima.	Mean of the minima.	Mean.	Mean of the maxima.	Mean of the minima.	Mean.	Mean of the maxima.	Mean of the minima.	Mean.	Mean of the maxima.	Mean of the minima.	Mean.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
January	11.0	28.4	5.8	16.5	5.9	−13.7	−3.9	35.5	6.9	22.1	18.5	−2.6	7.85
February	11.9	29.5	5.2	17.2	27.3	4.0	15.6	24.7	6.9	15.7	27.2	6.2	16.70
March	23.5	31.9	8.1	19.8	41.6	15.6	28.5	34.1	13.6	23.8	37.1	18.2	27.70
April	42.6	63.0	33.0	48.3	47.5	21.0	34.2	53.7	30.0	44.3	48.6	22.2	44.30
May	52.6	61.6	38.8	50.3	59.5	29.5	44.5	62.0	37.0	49.5	65.8	38.0	49.50
June	60.9	73.2	49.2	61.2	72.7	47.8	60.2	71.4	48.6	60.0	74.1	51.2	62.60
July	68.0	82.9	50.9	66.9	77.6	53.1	65.3	84.9	55.0	69.9	78.3	55.5	66.90
August	67.2	79.1	53.6	66.3	81.2	49.4	65.3	80.0	48.5	64.2	82.7	54.6	68.60
September	56.8	77.8	44.6	61.2	67.2	38.5	52.8	76.4	47.0	61.7	74.7	44.6	59.60
October	44.0	61.8	31.0	46.4	62.6	31.1	46.3	53.5	31.3	42.4	58.1	30.9	44.50
November	27.3	37.2	15.4	26.3	46.4	17.2	31.8	44.6	20.4	32.5	44.8	18.0	31.40
December	18.6	25.4	3.6	14.5	36.9	10.2	23.5	27.7	6.6	17.1	17.4	0.0	8.70
Annual	40.3	54.3	28.0	41.9	52.2	24.5	38.8	54.0	29.5	41.5	52.8	28.0	40.70

[a] The weather records for Dickinson have been kept at the experiment farm since March, 1906, and thus the data given are almost identical with those obtaining at the plats, as the two points are less than a quarter of a mile apart.

[b] These figures are based on records beginning in 1893, when the first observations were taken.

The most striking thing to be noted in view of the fact that a considerable percentage of the alfalfa plants lived through the winter, despite their lack of vigor due to imperfect inoculation and drought, is that the mean for January, 1906 (—3.9° F.), was 14.8 degrees colder than the normal temperature that had prevailed up to that time for that month, based on a 13-year record.

March, 1907, was slightly warmer than usual, but the snow covering remained until practically the 15th of the month. Though a slight growth began to show in many plants in April, decidedly inhibitive minimum temperatures continued throughout the month. There were killing frosts May 1–10, 13–15, 18–19, 26–27, and a final one on June 5.

The weather was such that the spring awakening was almost as gradual as the enforced dormancy of autumn. It was on account of this unusual combination of autumn drought, the gradual coming of winter, the protective covering of snow, and the gradual return of spring that some of even the tenderest alfalfa varieties came through this winter, which was one of almost unparalleled severity.

TERMINATION OF EXPERIMENTS BEGUN IN 1906.

Although a moderately good stand of alfalfa was obtained, the average for all plats on the sandy soil being 72.7 per cent and for those on the loam 84.6 per cent, the condition of the 1906 seedings was never satisfactory. The following statement upon this experiment is found in the records for 1906: "The alfalfa on these plats is a failure, due almost entirely to acute nitrogen starvation. The plants were not inoculated * * * and they were of weak, sickly appearance."

This lack of inoculation primarily, together with the dry autumn of 1906 and the severe winter that succeeded it, kept the plants in an unthrifty condition. Following this, the summer of 1907 was one of the driest of recent years. A total of only 13.67 inches of rain fell, while in 1906 and 1908 there were 19.09 inches and 19.50 inches, respectively.

This combination of trying conditions kept the plats in such an unpromising state that in the late autumn of 1907 they were plowed up to make room for other crops.

FIELD PLAT EXPERIMENTS AT DICKINSON, N. DAK., BEGUN IN 1907.

In the spring of 1907 a second experiment was started. Only four regional strains were seeded. Two samples of American alfalfa, one from Colorado and one from Utah, and two strains that had shown some degree of hardiness in the 1906 experiments, one from Turkestan and one from Simbirsk, Russia, were selected. At this time no seed of the Grimm alfalfa of Minnesota was available for use.

DIVERSITY IN PREVIOUS TREATMENT OF LAND USED.

The different portions of the field on which the experimental plats were located had not had the same cultural history. The virgin sod was broken in different years in some cases; some parts in autumn, others in spring; one part was left without a crop the first year, in other years the different parts bore different crops; one part received a dressing of rotted manure in a year when none of the others were fertilized.

These diversities of cultural history furnished an unusually good opportunity to study their effect on cold resistance. As interesting differences occurred in the amount of winter loss on different areas of the field, Table V and text figure 1 are inserted to show the different treatments these areas had received. As the 1908 field plats to be

discussed later were seeded on an adjacent part of the same field, they also are shown in the figure.[a] Table V presents the history of

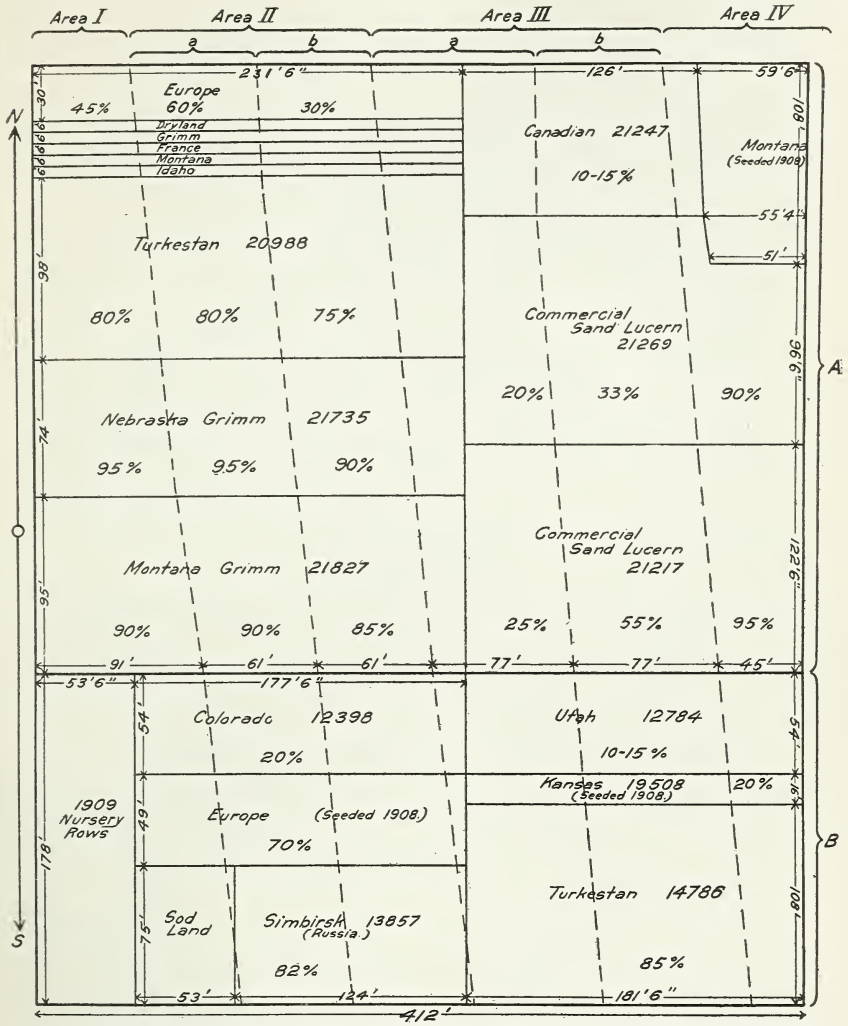

FIG 1.—Ground plan of the experimental field plats of alfalfa in 1907 (*B*) and 1908 (*A*), showing their location and estimated percentage of stand in June and August, 1909, and, in connection with Table V, the previous cropping and treatment of the various areas composing the field. (Scale, 1 inch=100 feet.)

[a] The 1908 field plats are fully discussed on pages 23 to 30, inclusive, but the writer's desire to call especial attention to the fact that the great differences in stand observed in 1909 on the various portions of these plats are due in large part to tillage effects and to differences in previous cropping and not to winterkilling.

The extent to which winterkilling was effective in thick as compared with thin stands may be seen best by a study of Table VIII, page 23. A comparison of the two "Total" and two "Loss" columns in this table shows that the percentage of loss was greater in every case on the square yard having the thinner stand; that is, the smaller total number of plants.

each area of the plats shown in figure 1. Estimations of the stand were made early in June, 1909, and again late in August.

TABLE V.—*Record of previous crops grown and of treatment given the land used for the experimental field plats of alfalfa in 1907 and 1908.* [*See also fig. 1.*]

Year.	Area I.	Area II.	Area III.	Area IV.
1904	Virgin prairie	Virgin prairie	Prairie—had been broken some years before, cropped, and then allowed to return to sod.	Virgin prairie.
1905	Broken in spring, not seeded, and grew up to Russian thistles.	Virgin prairie	Rebroken in spring and sown to oats. Fall-plowed.	Virgin prairie.
1906	Small-grain plats. Plowed and disked in autumn.	Broken up in October.	Grain. Fall-plowed .. *B*, Manured on stubble in autumn.	Broken up in October.
1907	*B*, Alfalfa (1907 field plats). *A*, Oats, stubble manured.	*B*, Alfalfa (1907 field plats). *A*, Oats, stubble manured.	*B*, Alfalfa (1907 field plats). *A*, Oats, stubble manured.	*B*, Alfalfa (1907 field plats). *A*, Oats, stubble manured.
1908	*B*, Alfalfa (1907 field plats). *A*, Alfalfa (1908 field plats).	*B*, Alfalfa (1907 field plats). *A*, Alfalfa (1908 field plats).	*B*, Alfalfa (1907 field plats). *A*, Alfalfa (1908 field plats).	*B*, Alfalfa (1907 field plats). *A*, Alfalfa (1908 field plats).
1909	*A* and *B*, Alfalfa	*A* and *B*, Alfalfa	*A* and *B*, Alfalfa	*A* and *B*, Alfalfa.

SOIL PREPARATION, WEATHER CONDITIONS, AND OTHER OBSERVATIONS DURING 1907 AND 1908.

In the spring the land for the 1907 plats was double-disked and harrowed on April 25 and double-disked crosswise and harrowed on June 1. Seeding took place on June 5, after a good rain. The rainfall of the summer was fairly adequate, though almost half of the 4.82 inches shown in Table II for July, 1907, occurred in two heavy storms only three days apart. Over half of the August rain fell in one storm. The autumn was dry. September had about a normal precipitation, while October had only 0.10 inch and November only 0.02 inch.

The first killing frost did not occur until September 29. Before this time growth had stopped and the plants had become practically dormant because of the dry weather. Russian thistles, more drought resistant than alfalfa, came up thickly and overtopped the latter. An ideal plant covering to hold snow was created. On October 11, 1907, the condition of the plats was noted. The estimated percentage of stand on this date for each plat was as follows:

	Per cent.
Turkestan (S. P. I. No. 14786)	80
Simbirsk, Russia (S. P. I. No. 13857)	70
Utah, irrigated (S. P. I. No. 12784)	90
Colorado, irrigated (S. P. I. No. 12398)	90

The winter of 1907–8 was an unusually mild one; the average temperature for the winter months was 20.4° F., this being almost 7 degrees above the 16-year normal.

The lowest temperature of the winter occurred on February 1 and was preceded by two days of snow. This was the only really cold spell experienced during that season, and the alfalfa was amply protected by snow throughout the period.

Mild as this winter was, some winterkilling occurred in all the strains. The amount was negligible in the Turkestan and Russian strains, the former showing the smaller loss. The Colorado and Utah plats suffered some loss, though not enough to reduce them to unprofitableness. All stands were sufficient to justify leaving the plats over during the winter of 1908–9. They will receive further discussion in connection with the field plats seeded in the spring of 1908.

A fact of some interest was noted regarding the comparative hardiness of alfalfa and red clover during this dry open winter. Six plats of the latter on land adjacent to the Simbirsk and Turkestan plats showed losses in stand ranging from 55 to 95 per cent.

In order to show the temperature conditions endured by the 1907 seeding as compared with the 1906 and 1908 experiments, Table VI is presented.

TABLE VI.—*Monthly mean temperatures for the winters of 1906, 1907, and 1908, at Dickinson, N. Dak.*

Month.	Monthly mean.			
	Average for 16 years.	1906–7.	1907–8.	1908–9.
	°F.	°F.	°F.	°F.
November	27.3	26.3	31.8	32.5
December	18.6	14.5	23.5	17.1
January	11.0	−3.9	22.1	7.9
February	11.9	15.6	15.7	16.7
March	23.5	28.5	23.8	27.7
Mean	18.5	16.2	23.4	20.4

The Turkestan and Russian strains of alfalfa not only did not suffer serious loss, but by the summer of 1909 showed an improved condition of stand. This change was one of appearance and not an actual thickening of the stand. It varied in the different areas shown in figure 1 and appeared to be due in large part to a progressive inoculation of the soil with nitrifying bacteria as the plants became better established.

The most important fact gleaned from the small experiment begun in the spring of 1907 was that the common form of alfalfa, which in a little more than half a century has been extended so generally over the western half of the United States and which has for many years proved sufficiently hardy throughout Kansas and over a large part

of Nebraska, is not cold resistant enough to endure perfectly even a mild winter in the coldest parts of the Great Plains.

The autumn of 1907 furnished another illustration of the importance of dry weather during the fall in producing dormancy. The winter, as a whole, was an open one, but there was a snow covering of utility during the only critical period. Although the winter was an abnormally mild one, these two factors were probably dominant in the comparatively successful wintering over of the two American strains. These same factors and a greater inherent hardiness appear to have produced the better results observed in the Turkestan and Simbirsk varieties.

WINTERKILLING (1908–9) AND YIELDS (1909) OF THE 1907 FIELD PLATS.

The winter of 1908–9 is discussed fully later in connection with the 1908 row experiments; hence it need not be taken up in this connection. Its effect on the 1907 field plats, as determined in the spring of 1909, is shown in Table VII. The figures presented in this table were secured in May, 1909, by counting the living plants and the winterkilled crowns on selected square yards which showed the highest and lowest amount of loss.

TABLE VII.—*Results of experiments showing the relative proportion of winterkilling (1908–9) of the alfalfas in the experimental field plats of 1907 and their yield in 1909.*

S.P.I. No.	Strain.	Plants on square yard showing the least winterkilling.				Plants on square yard showing the greatest winterkilling.				Yield of whole plat.
		Living plants.	Dead plants.	Total.	Loss.	Living plants.	Dead plants.	Total.	Loss.	
13857	Simbirsk, Russia....	*Number.* 69	*Number.* 23	*Number.* 92	*Per cent.* 25.00	*Number.* 45	*Number.* 33	*Number.* 78	*Per cent.* 42.30	*Pounds.* 2,065
12398	Colorado....	236	70	306	22.87	32	191	223	86.09	1,131
14786	Turkestan...	120	10	130	7.69	31	30	61	49.18	2,502
12784	Emery, Utah.	20	91	111	81.98	4	127	131	96.94	1,175

A comparison of the figures in the percentage of loss columns in Table VII will show how great the differences in winter loss were in the same varieties, but on different parts of the same plat. Some discussion of the particular factors that may have produced these differences will be taken up in connection with the 1908 field plats.

Attention here is directed only to Colorado alfalfa, S. P. I. No. 12398, which originally had an unusually thick stand over the whole plat. On the square yard where the least winterkilling had taken place only 70 plants (23 per cent) out of 306 were killed, while on the other 191 (86 per cent) out of 223 succumbed.

FIELD PLAT EXPERIMENTS AT DICKINSON, N. DAK., BEGUN IN 1908.

WINTERKILLING AND YIELDS.

In the spring of 1908 a second series of field plats was seeded by the subexperiment station at Dickinson, N. Dak. These are in charge of the junior writer cooperating with Mr. J. M. Westgate, Agronomist in the Office of Forage-Crop Investigations. As may be seen by reference to figure 1, the new seedings are situated immediately north of the 1907 field plats and share with these the diversities in the previous cropping and treatment shown in Table V.

Counts of all the living and dead plants on selected square yards were made, as in the case of the 1907 seedings. The results are shown in Table VIII.

TABLE VIII.—*Results of experiments showing the relative proportion of winterkilling (1908–9) of the alfalfas in the experimental field plats of 1908 and their yield in 1909.*[a]

S.P.I. No.	Variety or strain.	Plants on square yard showing the least winterkilling.				Plants on square yard showing the greatest winterkilling.				Calculated yield per acre.
		Living plants.	Dead plants.	Total.	Loss.	Living plants.	Dead plants.	Total.	Loss.	
		Number.	*Number.*	*Number.*	*Per cent.*	*Number.*	*Number.*	*Number.*	*Per cent.*	*Pounds.*
20988	Turkestan	99	8	107	7.47	60	30	90	33.33	1,156
21735	Grimm (Nebraska)	87	1	88	1.13	42	5	47	10.63	1,474
21827	Grimm (Montana)	76	0	76	0.00	51	0	51	0.00	1,487
	Europe[b]	88	0	88	0.00	40	9	49	18.35	2,136
21247	Canada	78	9	87	10.34	8	6	14	42.85	912
21269	Darmstadt, Germany	100	41	141	29.07	22	11	33	33.33	1,603
21217	....do	45	0	45	0.00	18	13	31	41.93	1,960
19508	Kansas[c]	65	36	101	35.65	16	23	39	59.00	1,044

[a] Mr. Charles H. Clark, Special Agent, Crop Physiology and Breeding Investigations, Bureau of Plant Industry, rendered painstaking and efficient help in making many of the determinations presented in this paper. Mr. O. J. Grace, Acting Superintendent, also rendered much assistance.

[b] This plat is located between two plats sown in 1907. The seed was imported as sand lucern from Europe for the substation. On an examination of the plants it proves to be neither the true sand lucern nor the so-called commercial or false sand lucern. It is almost wholly lacking in variegated flower color, and by its general habit of growth, appearance, leafage, etc., suggests the possibility that it is a Turkestan alfalfa adulterated with a small quantity of ordinary middle European alfalfa. The plat shown in the upper left-hand corner of figure 1 is from the same seed. Its yield was not taken.

[c] This plat is also located between two 1907 plats (see figure 1). According to Mr. J. M. Westgate it was grown from seed a part of which at least was from a field planted with variegated-flowered alfalfa seed, presumably procured originally from central Europe.

OBSERVATIONS ON DIVERSITY OF CONDITIONS.

Several interesting conditions were observed on both the 1907 and 1908 plats. These are shown in a measure in Tables VII and VIII and in figure 1. The following deserve especial consideration:

(1) Differences in the original stand on different parts of the same plat. This becomes evident on comparing the columns marked "Total" for each plat shown in Table VIII.

(2) Differences in the amount of winterkilling on different parts of the same plat. In these cases the greater percentage of loss appears to have taken place on the part that had the poorer stand originally.

(3) Differences in the percentage of loss in the two Grimm samples, despite the fact that these were both grown from the same original stock.

(4) Differences in the color and vigor of the plants and finally in the amount of growth on the different areas. The latter finds partial expression in the diversities in yield.

(5) Differences in yield which show practically no correlation to any of the conditions mentioned above except the last.

Differences in Original Stand.

That some of the differences in the original stand are due to differences in the preparation of the soil and the previous cropping is probable, as they follow exactly the division lines of the "lands," shown by the broken lines in figure 1, page 19. How sensitively alfalfa reacts to even slight variations in preparing the soil is shown on both Areas II and III, but especially on the latter. Here the uphill or east furrows have a much better stand and higher growth than the downhill or west furrows.

To show more concretely the diversities in stand on the differently treated strips of the field after the winter of 1908–9, the estimated percentage on each for all plats is stated in figure 1. In the case of plat 21217 the difference in estimated stand between the east and west ends amounts to fully 70 per cent.

The soil was very dry in the fall of 1906 when the sod was broken up on Area II, so dry, in fact, that the plowman had great difficulty in getting his plow to "bite" when going down hill.

Differences in Amount of Winterkilling.

The differences in the amount of winterkilling are traced with greater difficulty and less certainty than those producing differences in the original stand. However, there are certain interrelations. The square yard of each plat showing the thinner stand suffered the greater loss in each case. Hence, a lack of thickness of stand itself probably has an important bearing. An inferior snow-holding capacity results and a greater consequent exposure to the weather. Furthermore, thick stands, through greater transpiration, more quickly exhaust excess moisture from the soil. The probable importance of this factor is more fully discussed later.

Another factor both directly and indirectly of importance in winterkilling on the 1907 and 1908 field plats is inoculation. Its direct importance rests on the robustness, vigor, and generally greater hardihood that results from perfect nutrition. Inoculation conduces to a better root development, higher growth, and more leafage, the two latter making a more nearly perfect covering to bind the winter's snow.

DIFFERENCES IN COLD RESISTANCE OF TWO SAMPLES OF GRIMM ALFALFA.

The difference in the amount of winterkilling in the two Grimm samples raises the important and interesting question as to what cause or causes this is due.

Both the Montana and Nebraska seed were grown from S. P. I. No. 12991, the former at Chinook, in northern Montana, and the latter at Alma, in southern Nebraska, near the Kansas line. Grimm No. 12991 was grown in Minnesota in 1904. The weakness of the Nebraska race as compared with that from the Montana seed was only slightly apparent where the stand was thickest, but amounted to over 10 per cent on the square yard with the thinner stand.[a]

[a] The difference in the winter hardiness of the two Grimm samples is not so great as to be outside the limit of possible error in field plat work. This is especially true of the present plats, which were put in only with ordinary care on land showing a wide range of diversity in tillage effects. Nevertheless, several possibilities that suggest themselves as being concerned in this difference in cold resistance deserve notice in this connection:

(1) Free hybridization between the Grimm field and neighboring fields of the far less hardy ordinary alfalfa. Common alfalfa is grown in both sections; hence there would be some tendency toward equalization as to the factor. However, natural selection toward cold resistance is operative every winter in northern Montana and very rarely operative in southern Nebraska. The result of this should be a hardier race of common alfalfa in Montana than exists in Kansas or in Nebraska south of the Platte River. There is little doubt that this is actually the case, both from experimental evidence and from the fact that there is a general demand for Montana seed in preference to Kansas, Nebraska, or Utah seed for use in cold regions. Hence, the weakness that probably results from hybridization would be greater in a measure in the southern-grown race.

(2) Further selection toward cold resistance in Montana and a slight reversion, if anything, in southern Nebraska. Alma is approximately 300 miles farther south than the Grimm section of Minnesota and 600 miles south and almost as much east from Chinook.

The selective power of the Montana as compared with the Nebraska climate is shown in a measure by the monthly minima for Alma and Chinook presented in the following table. The winters shown are those that intervened between the seeding, which took place in the spring of 1905, and the harvesting in the fall of 1907 of the seed used at Dickinson on the 1908 field plats.

Minimum monthly temperatures for the cold months of 1905, 1906, and 1907 at Chinook, Mont., and Alma, Nebr.

Locality.	Winter of 1905–6.						Winter of 1906–7.					
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Chinook[a]	− 8	−28	−18	−21	−16	−25	15	− 7	−15	−45	−43	− 8
Alma	17	5	6	− 3	− 2	−14	16	7	2	0	− 6	

[a] The records for both Chinook and Havre, Mont., were used in securing these minima on account of gaps in the record of the former.

Another point to be noted in Table VIII with reference to the Grimm samples is that the one whose loss from winterkilling was greater, nevertheless gave practically the same yield as the one that suffered no loss. This is due to the fact that the Nebraska Grimm alfalfa had fully 5 per cent better stand on the plat as a whole than the Montana Grimm.

The following comparison of their germination gives a reasonable explanation of this difference in stand, and at the same time brings to light another difference in the progeny of S. P. I. No. 12991 as grown in Montana and Nebraska quite as profound as the diversity in hardiness, namely, in the percentage of hard seed.

S.P.I. No.	Strain.	Germination.	Hard seed.
		Per cent.	*Per cent.*
21735	Grimm (Nebraska)	77.5	16.00
21827	Grimm (Montana)	45.5	42.75
12991	Grimm (Minnesota)	60.0	36.50

The percentages of germination and hard seed of the Nebraska-grown stock are the average of five tests, those of the Montana of two tests. These tests were made in the winter of 1908. In the spring of 1909 both strains were again tested, with the following results:

S.P.I. No.	Strain.	Germination.	Hard seed.	Length of test.
		Per cent.	*Per cent.*	*Days.*
21735	Grimm (Nebraska)	83.5	10.0	4
21827	Grimm (Montana)	53.5	30.5	5

The subject of hard seed is little understood, and attention here is directed to it only because it accompanies an observable difference in hardiness in the same race grown under unlike climatic conditions.

The difference in winter weather shown by these minima is a great one, and might of itself be a sufficient explanation of the difference in the winter loss of the two Grimm plats.

(3) The third factor of probable influence is new-place effect, due to a disturbance of local adjustment in the variety brought about by transporting it from one set of conditions to another. The warm climate at Alma would be especially likely to call forth new-place diversities. It is of course impossible to determine the amount of change any one of the factors discussed may have produced. Their potency, however, is scarcely open to question.

The important phenomenon of local adjustment in cotton varieties has been discussed recently by Mr. O. F. Cook in "Local Adjustment of Cotton Varieties," Bulletin 159, Bureau of Plant Industry, September, 1909. Observations made the past season by the senior writer of the present paper indicate that this phenomenon also occurs in alfalfa when subjected to a change of place.

Differences in Color, Vigor, and Amount of Growth of Plants.

The differences in the color, vigor, and amount of growth of alfalfa plants find partial expression in Table VIII in the figures giving yields, which are discussed below. They are so evident on the plats themselves as to suggest immediate inquiry.

On September 1, 1909, the plants of the 1908 seedings on Area IV (fig. 1, p. 19) averaged fully 16 inches high, those on Area III about 8 inches, while those on Areas I and II averaged about 7 and 8 inches, respectively. Furthermore, the plants of the thick stand on Area IV had the healthy dark-green color of well-inoculated alfalfa, while Areas I and II had unthrifty plants of a pale yellowish green. On Area III even the plants making up the thin stand on both up and down furrows showed more growth and better color than did the plants on Area II.

Differences in Yield.[a]

In view of the differences in the extent of winterkilling and in the carefully estimated percentages of present stand, shown in figure 1, the diversities in yield for the different plats are decidedly interesting. Take, for example, S. P. I. No. 20988, which lost only about 7½ per cent of the plants on a selected square yard where the stand was thickest and 33½ per cent where thinnest. Compare this with S. P. I. No. 21269, which lost over 29 per cent on the better part of the plat and 33½ per cent where the stand was poor. Although there is no great difference in the average number of living plants remaining on the better portions of both plats, and the number of living plants on the poorer part of No. 20988 is fully three times as great as that on the corresponding part of No. 21269, the latter outyielded the former by 450 pounds per acre.

About September 1, 1909, careful estimates were made and the following comparison shows the stand on the different areas of both plats:

S.P.I. No.	Strain.	Good.	Medium.	Poor.
		Per cent.	*Per cent.*	*Per cent.*
20988	Turkestan	80	80	75
21269	Commercial sand lucern	90	33	20

A similar disagreement in yield and stand exists between S. P. I. Nos. 21217, commercial sand lucern, and 21827, Montana-grown Grimm alfalfa. Although the former has a thin stand over two-thirds of the plat and showed some winterkilling where the stand was

[a] See Table VIII, p. 23, in connection with this discussion.

thin, while the latter was wholly uninjured and has on the whole a far thicker stand, still No. 21217 gave a yield of 2,000 pounds per acre, while No. 21827 produced only 1,487 pounds.

An even more striking result is apparent on comparing Turkestan, S. P. I. No. 20988, in Table VIII, with Utah, S. P. I. No. 12784, in Table VII. The average winterkilling for the two parts of the Turkestan plat was about 20 per cent, with 80 per cent of a perfect stand remaining. The Utah plat winterkilled almost 90 per cent and still, according to the scales, produced as much hay as the Turkestan. A part of this discrepancy may be explained by the general inoculation of the surviving plants of the Utah strain, but the controlling factor was the weeds harvested and weighed with the alfalfa.

Weeds constituted a large proportion of the product of all the plats or parts of plats which had thin stands originally or which suffered severe winter losses. In the 1907 section of the field the latter condition applies particularly to the Utah, Kansas, and Colorado strains, and the former in a measure to all parts of the plats included in Areas II and III. On the western two-thirds of the east tier of the 1908 plats the stand of alfalfa was very light, and weeds made up a large part of the hay yield. The three plats on the west side of the field (see fig. 1, p. 19) had sufficiently thick stands of alfalfa to hold the weeds under complete check. The Canadian plat's product, small as it is, was still more largely made up of weeds. The original seeding on this plat was very thin.

These differences are traceable almost wholly to inoculation. Almost one-third of plat 21217 (all of Area IV) is perfectly inoculated, while only scattering plants on 21827 show signs of inoculation. As previously stated, on September 1 the growth on Area IV averaged about 16 inches high, while that on Areas I and II was less than 8 inches. The yields given are for the first crop. Those for the second crop vary even more strikingly, but are not given, as rains made it necessary to scatter and rebunch the hay several times. In doing this some confusion arose, making the figures as a whole unreliable, hence their omission.

That the diversities in yield commented upon are really due to a difference in the extent of inoculation is readily apparent upon even a casual examination. A comparison between the 1908 plats (Table VIII) and the 1907 plats (Table VII) furnishes additional evidence that is of interest. The latter are uniformly inoculated, while the former are not.

The average stand on Turkestan plat No. 14786, seeded in 1907, is practically identical with that of Turkestan No. 20988, seeded in

1908. The yield of the former, 2,502 pounds per acre, was more than twice that of the latter, which gave only 1,156 pounds.

Another factor with reference to the 1908 field plats that deserves mention is a difference in the amount of seed applied to the different plats. The following shows the rate per acre at which the seeding of the various strains of alfalfa was done:

	Pounds.
Turkestan (S. P. I. No. 20988)	15.4
Sand lucern (S. P. I. No. 21217)	13.7
Sand lucern (S. P. I. No. 21269)	9.2
Grimm (S. P. I. No. 21827)	13.9
Grimm (S. P. I. No. 21735)	10.2
Canadian (S. P. I. No. 21247)	4.4
Kansas (S. P. I. No. 19508)	14.9

IMPORTANCE OF INOCULATION.

As the foregoing discussion shows, many factors, some of them probably unrecognized, interacting in a complex and imperfectly understood manner, must be taken into consideration in comparing the yields given of the different plats, and too great reliance must not be placed on them.

Another plat of Grimm alfalfa seeded in 1908 with Minnesota seed gives an opportunity for comparing the same variety under uniform field conditions with the Grimm as grown under the very dissimilar conditions prevailing on the 1908 experimental seedings. The small field of Grimm which is referred to as the "valley plat" is located in a slight depression farther up the slope and about 600 feet northwest of the 1908 field plats. It was seeded the same day as the latter and has a perfect stand except at one point where evidently some of the drill hose became clogged. The valley plat contains a net area of 1.22 acres and produced 4,098 pounds of cured hay per acre for the first cutting. This yield should be compared with the Nebraska-grown Grimm which had only a slightly poorer stand, but produced less than 1,500 pounds of hay per acre. The former had general inoculation, while the latter had practically none. It might be mentioned that a pure culture was used to inoculate the seed sown on the Nebraska Grimm plat, while the valley Grimm plat was inoculated both with a pure culture and with alfalfa dirt. In this case the soil inoculation appears to have been the more efficacious, though diversity in conditions makes satisfactory comparisons impossible. The valley plat soil is somewhat better, though the two soils do not differ materially. The valley plat, originally virgin prairie, was broken and disked July 20, 1907. It was well disked and harrowed

in the spring of 1908 and seeded to alfalfa May 27, 1908. It is commonly believed that alfalfa does not do well on new ground.

That inoculation has even more direct relations to cold endurance than those already discussed appears to be shown by observations made during the autumn of 1909.

On the night of September 25 a light frost occurred. During the following day Mr. Clark made the interesting observation that the well-inoculated parts of all plats remained uninjured, while the parts that had only slight inoculation or none at all were markedly affected. During the night of October 8 a sharp frost (24° F.) occurred, which affected all areas alike except Area IV. The latter had the heavy growth, dark-green color, and general robustness that accompany perfect inoculation. The same observations were recorded for the valley plat of Grimm alfalfa, which has like evidences of inoculation but is located farther up the slope and northwest from the 1907 and 1908 field plats; however, in this case a slightly higher altitude must also be taken into consideration.

Similar observations as to the frost resistance of inoculated plants were also recorded in the case of well-inoculated row experiments located alongside the field plats.

DRILL-ROW AND HILL EXPERIMENTS AT DICKINSON, N. DAK., BEGUN IN 1908.

In the early spring of 1908 arrangements had been concluded for a more comprehensive test of the hardiness of alfalfa than any previously undertaken in the United States.

In accordance with the plan that was made, sixty-eight strains or numbers were sown on May 15 in duplicate series. One complete set was sown in drill rows 3 feet apart with one row of each kind. These rows are 50 feet long, and as the summer advanced the plants in them were thinned out to one every 8 to 12 inches, leaving only the most vigorous plants. The second series was in hills 2½ feet apart. There were 25 hills of each strain which during the summer were thinned out to one individual in each hill. The hills of each strain were planted at the end of the drill rows, so that both methods of seeding were combined in one continuous row.

The experimental plat, the soil of which is a rich, black, sandy loam, lies near the base of a ridge that extends in a general east and west direction and furnishes some degree of protection from the prevailing winter winds which come from the Northwest. The plat slopes slightly toward the middle on account of a slight depression running diagonally across it. This affects nearly all rows equally.

Soil of Experimental Area, Previous Cropping, and Preparation.

The area used for the drill-row and hill experiments was virgin prairie which was first broken in the spring of 1905 and planted to vines. The land was plowed in the fall of 1905 and then disked. It was disked and harrowed in the spring of 1906 and sown broadcast to small clover plats. The land was plowed in the fall of 1907 about 6 inches deep and worked down. The ground was well worked in the spring of 1907 with a disk and harrow before starting the alfalfa experiment. The soil was inoculated by sowing earth, taken from an experimental alfalfa plat on the station farm, broadcast at the rate of about 400 pounds per acre.

The soil would probably be described as a fine black, sandy loam—the Morton loam as described by the Bureau of Soils. The following mechanical analysis is furnished by the Bureau of Soils of the United States Department of Agriculture:

No. of sample.	Description of soil analyzed.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
13634	Top, 8 inches.....	0.4	0.9	1.4	10.6	19.3	47.3	20.1
13635	Second, 8 inches.....	.3	.3	.9	9.7	20.4	42.0	26.5

Origin of Strains used in Experiment.

The strains used in the experiment were chosen with a view to assembling a fairly complete collection of the cultivated alfalfas of the world; but in the case of American-grown seed no attempt was made to represent a climate milder than that of central Utah, previous observations having shown that no degree of hardiness worthy of note could be found in seed from the milder States of the West and Southwest. Irrigated and unirrigated or dry-land strains were included in the plan in order to secure accurate data as to whether the characters producing drought resistance were in any way correlated with those producing cold resistance.

To give a fuller conception of the wide range of climatic and other conditions represented by the sixty-eight strains, Table IX, showing their geographical origin, is presented.

TABLE IX.—*Record of the geographical origin of the sixty-eight strains of alfalfa grown in the drill-row and hill experiments at Dickinson, N. Dak., in 1908–9.*[a]

North America (26):
- Canada (2).
  - 42, 43.
- Mexico (2).
  - 44, 45.
- United States (22):
  - Colorado (1) irrigated.
    - 47.
  - Kansas (1).
    - 48.
  - Minnesota (1).
    - 51.
  - Montana (3) irrigated.
    - 12, 41, 49.
  - Nebraska (3).
    - 26, 50, 53 (dry land).
  - North Dakota (2).
    - 52, 68.
  - South Dakota (2).
    - 50, 54.
  - Utah (9).
    - Irrigated (4).
      - 1, 5, 10, 64.
    - Not irrigated (5).
      - 19, 22, 55, 56, 65.

South America (5):
- Argentina (3).
  - 14, 15, 16.
- Ecuador (1).
  - 13.
- Peru (1).
  - 11.

Europe (15):
- France (5).
  - 23, 24, 25, 57, 60.
- Germany (5).
  - 17, 58, 59, 62, 63.
- Italy (1).
  - 61.
- Russia (2).
  - 27, 29.
- Spain (1).
  - 21.
- Commercial (1).
  - 46.

Asia (19):
- Arabia (4).
  - 6, 7, 8, 9.
- Mongolia (3).
  - 2, 3, 4.
- Turkestan (12).
  - 28, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 67.

Africa (3):
- Algeria (2).
  - 18, 66.
- Tunis (1).
  - 20.

[a] The figures in parentheses indicate the number of strains from the country or State named, while those without parentheses refer to the numbers of the rows in which the strain was grown, as shown in Table XIII.

Numerous strains known to be tender, especially from foreign sources, were included for comparison. The least hardy of these were the Arabian and Algerian strains, and the Andean variety represented by the strains from Peru and Ecuador.

On account of the great interest that has been taken in Turkestan alfalfa, especially in the Northwest, where much has been claimed for it in the way of hardiness, a selection of twelve strains from that country was included in the test.

WEATHER CONDITIONS DURING THE SUMMER OF 1908.

The spring and summer of 1908 were exceedingly favorable for getting a catch of alfalfa. Seeding was completed on May 15 and was followed by prompt germination. A good stand was secured in practically all of the rows, such deficiencies as occurred being due chiefly to poor germination. As may be seen from Table II, the rainfall was ample. Indeed, all the conditions except a frost that occurred

on August 22, which did not do permanent injury, were more favorable than had prevailed in any previous year since experimental work began at this place. Growing weather continued without interruption until the 27th and 28th of September, on which dates killing frosts occurred. Thereafter the weather grew gradually cooler. Killing frosts came again on October 7, 10, and 11, and beginning with the 17th continued nightly with one exception to the end of the month. Nearly all growth had ceased in the strains in the nursery by October 23. The minimum temperatures fell gradually during the first half of November, culminating in zero weather on the night of the 14th.

By the end of September, when growth-inhibiting frosts began, all of the alfalfas had become fully established. They had been clipped once during the summer (on August 5), and the second growth had reached an average height of 12 inches or more. The crowns had stooled out well and the plants were vigorous and of a healthy color, having become well inoculated.

In discussing the experiments begun in the spring of 1906, emphasis was laid on the belief that the dryness that prevailed during the fall of that year was one of the very important favorable factors that enabled a part of all of the 22 alfalfas under test to pass unharmed through the unprecedentedly severe winter of 1906–7. This has been discussed in some detail earlier in these pages.

The following statement of the rainfall for September and October of 1906 and 1908 shows an important disparity:

	Average for 16 years.	1906.	1908.
	Inches.	*Inches.*	*Inches.*
September	1.04	0.25	1.67
October	.70	.14	2.47

Autumn Moisture and Its Effect on Dormancy.

In respect to the factor of autumn moisture and its effect on the dormancy of alfalfa plants, conditions in 1908 were vastly different from those of 1906. The figures given above show the wide difference in the quantity of rain that fell. In the humid portions of the United States a precipitation of approximately $1\frac{1}{2}$ inches in September and $2\frac{1}{2}$ in October occasions no comment, but in the dry parts of the Great Plains it is very unusual. Only one other October (that of 1898) during the 16-year period covered by the Dickinson records had a greater precipitation than that of 1908. The rains of these months fell in such a manner that they were largely taken up by the soil. Furthermore, the amount of moisture available to

each plant is far greater in stands sown in rows and hills than in thick stands secured by the ordinary methods of seeding. The appearance of the experiment on October 1, 1908, is shown in Plate I, figure 1 (frontispiece).

As a result of this moist condition, the plants went into the cold weather that came toward the end of October (16° F. on the 23d) in a comparatively unhardened condition. Temperatures inhibitory to growth occurred late in September and at intervals during October, but these did not occur frequently enough nor were they long enough sustained to produce the gradual and complete dormancy observed in 1906.

By the middle of November, zero weather having arrived shortly before, it was no longer possible to find growing stems either in the drills or hills. On the other hand, in the field plats mentioned in Tables VII and VIII, which were sown thickly in the usual way, it was possible as late as the 20th of the month to find plants with stems still in a fresh and growing condition.

Inasmuch as the winter as a whole dealt much less severely with the field experiments than with the rows, a careful canvass has been made of all possible explanations. It is rarely, if ever, possible to tell positively in such cases as this what particular factors brought about the results observed, but it seems probable that the field plats escaped the injury suffered by the hills and rows for some or all of the following causes: (1) The greater protection due to thick stand, the thicker stand serving to hold the snow; (2) the warmer location on a pronounced slope (the rows are located near the base of this slope); (3) the only cutting of the 1907 and 1908 field plats being done much earlier than the cutting of the rows, the tissues in the plants of the field plats had a chance to become hardened, and finally (4) on account of the dry condition of the soil in the plats as compared with the rows. The last factor might have acted directly upon the roots of the plants through the temperature and indirectly by bringing about a hardening of the tissues of the plants in the field plats. The dryness was brought about by the far greater run-off due to hard, uncultivated topsoil and sidehill location.

Amount of Soil Moisture in Alfalfa Stands of Varying Thickness.

Unfortunately, determinations of the percentage of soil moisture in the field plats, hills, and drill rows were not made in the autumn of 1908. In the spring of 1909, experiments were undertaken to determine the drying effect on the soil of alfalfa stands of varying thickness. In these experiments Grimm alfalfa plants from a 1908

seeding were transplanted into plats with definite distances between the plants. Early in November, 1909, the moisture in the soil in these plats was carefully determined to a depth of 4 feet. The results of these determinations and several others are presented in the following table:

TABLE X.—*Results of determinations showing the percentage of soil moisture in the plats of alfalfa broadcasted and planted in drill rows and in hills having stands of varying thickness, Dickinson, N. Dak., November, 1909.*

Depth.	Broadcast.	Drills. 3 feet apart.	Hills. 16 by 16 inches.	Hills. 24 by 24 inches.	Hills. 18 by 36 inches.	Hills. 36 by 36 inches.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
First foot	12.6	13.9	13.2	14.5	16.6	17.6
Second foot	9.7	11.9	13.7	14.7	15.5	16.8
Third foot	9.9	10.7	11.6	12.2	17.9	14.7
Fourth foot	8.4	14.5	12.4	16.1	18.8	18.7

It will be noted that in general the amount of moisture in the soil varies directly with the thickness of the plant covering, the thickly broadcasted plats having the least and the hills 18 by 36 and 36 by 36 inches apart the most moisture. That a similar condition prevailed in the autumn of 1908 to that shown in Table X for 1909 can not be doubted.[a] Moreover, it seems likely that the percentage of moisture in 1908 was much greater than in 1909, as the following comparison of the rainfall for the two years would indicate:

	1908.	1909.
	Inches.	*Inches.*
September	1.67	0.83
October	2.47	1.08

The distribution of the rainfall in 1908 was such that a greater degree of saturation probably resulted than in 1909. September,

[a] The soil moisture figures for both 1908 and 1909 are available for certain corn and wheat plats. The following percentages are the average for the top 3 feet of soil:

Corn.			Wheat.		
Date.	A.	B.	Date.	A.	B.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Oct. 21, 1908	21	21.4	Oct. 21, 1908	15.5	16.4
Nov. 11, 1909	14.8	14.6	Nov. 23, 1909	14.9	14.8

These plats received the same treatment both years.

1908, had eight days with rain; September, 1909, nine days. October, 1908, had six days with rain; October, 1909, had three.

The moisture determinations shown in Table X all relate to stands less than a year old. To determine whether similar conditions prevail in stands of greater age, with a varying thickness of the plant covering, 4-foot borings were also made in various places in the 1908 seedings. The results, which are corroborative, are presented in Table XI.

TABLE XI.—*Results of determinations showing the percentage of soil moisture in the 1908 experimental field plats and drill rows of alfalfa at Dickinson, N. Dak., in November, 1909.*[a]

Depth.	Thick stand. Plat 21217.	Thin stand. Plat 12784.	206 plants on 1,200 square feet.	171 plants on 1,200 square feet.	64 plants on 1,200 square feet.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
First foot	10.7	11.9	17.7	16.5	18.2
Second foot	9.7	11.7	13.2	14.0	18.5
Third foot	9.5	11.5	10.9	15.1	20.1
Fourth foot	8.3	11.4	11.1	15.6	17.0
Average	9.5	11.6	13.2	15.4	18.4

[a] The moisture determinations presented in Tables X and XI were made by Mr. John C. Thysell, through the courtesy of Prof. E. C. Chilcott, Agriculturist in Charge, Dry-Land Agriculture Investigations, Bureau of Plant Industry.

As in the case of the 1909 seedings shown in Table X, the quantity of moisture varies directly with the thickness of the stand, the area with the thinnest plant covering having on an average practically twice the amount of moisture of the thickest stand.

The thick and thin stands shown in the first and second columns of this table are located on Area IV, as shown in figure 1, and are adjacent. The Utah strain (S. P. I. No. 12784) was seeded in 1907 and winterkilled badly during the winter of 1908–9, so that only about 15 per cent of a stand remains on this, the best portion of the plat. The commercial sand lucern plat was seeded in the spring of 1908 and the portion on which the moisture determination was made has an estimated stand of 95 per cent. The determinations shown in the third column of Table XI are from borings made between drill rows 39 and 40 (commercial Turkestan and Wheeler's acclimatized Turkestan), as shown in Table XIII; those in column 4, between rows 51 and 52 (Minnesota and North Dakota Grimm); those in column 5, between rows 58 and 59 (two samples of commercial sand lucern from Germany).

It is evident from these differences in the amount of soil moisture that just comparisons in regard to the winterkilling of alfalfa can not be made in the future without taking the differences into account. If, as appears likely, a higher moisture content produced a severer test

condition, an accurate comparison of winterkilling can not be made between the rows in question, as the ones with a thinner stand will have been subjected to more trying conditions than the others. The result of these moisture determinations also indicates that the progressive thinning of a stand, which goes on more or less rapidly according to the hardiness of the strain used, is in itself a menace to the success of any field.

Weather Conditions during the Winter of 1908–9.

On November 25 and 26, 1908, no less than 7 inches of snow fell, but a severe blizzard on November 30 blew this into banks, leaving the alfalfa nursery, which is located on the north side of a shelter belt of young, deciduous trees, practically bare of snow. On December 1 a minimum of −10° F. was recorded. There was nothing particularly worthy of note in the weather of December, but as compared with the same month in 1906 very little snow fell. In 1906 the total fall for the month was 7.5 inches, with a like amount on the ground at the end of the month, while in December, 1908, the total fall was 2.4 inches, with only 2 inches on the ground at the end of the month. In the alfalfa nursery, on account of the lack of a sufficiently dense plant covering to hold the snow, there was even less than this. This resulted in the rows and hills having practically no snow covering to protect the plants.

Plate II, figure 1, illustrates more effectively than can be described the great importance of even a light covering of snow. The small patch of red clover seen in the middle of the foreground is all that remained on a series of plats immediately adjacent to the 1907 field plats of alfalfa. These plants have lived over without doubt as a result of their being protected by 2 or 3 inches of snow. Extending along the right edge of the clover is the rather high ridge of another season's back furrow, which held a sufficient crust of snow to prevent the extermination of this group of plants, while the loss on the remainder of the plats was 100 per cent. A similar phenomenon explains the living over of the alfalfa plants, but in this case the growth made during the previous autumn which was not removed served to hold the snow. This point will be more fully discussed later.

Table XII shows the complete weather record, except the wind direction and the character of the day, for January, 1909, at Dickinson. It is presented here to make possible a careful comparison of the weather of this month with that of January, 1907, which is shown in Table III.

TABLE XII.—*Daily record of temperature and precipitation for the month of January, 1909, at Dickinson, N. Dak.; latitude, 46° 50′ N.; longitude, 102° 50′ W.; altitude, 2,453 feet.*

Date.	Temperature.				Precipitation.		MONTHLY SUMMARY.
	Maximum.	Minimum.	Range.	Record at 6 p. m.	Snowfall.	Depth of snow on ground at time of observation.	
	° F.	° F.	° F.	° F.	*Inches.*		*Temperature.*
1	23	−12	35	14	.....	.....	Mean maximum, 18.5° F.
2	39	2	37	.....	.....	.....	Mean minimum, −2.6° F.
3	31	18	18	19	.....	.....	Mean, 7.85° F.
4	20	−17	37	−16	0.2	.....	Maximum, 44° F.; date, 27th.
5	−16	−25	9	−20	.1	.....	Minimum, −31° F.; date, 6th.
6	−15	−31	16	−17	.....	.....	Greatest daily range, 44° F.
7	− 8	−19	11	−16	.7	.....	*Snow.*
8	−13	−25	12	−20	.1	.....	Total fall, 2.7 inches; on ground 15th, — inches; at end of month, very little, and that in spots.
9	−15	−25	10	−19	.2	.....	
10	−13	−21	8	−18	.2	.....	
11	− 6	−28	22	−14	.....	.....	
12	6	−20	26	− 5	.....	.....	
13	− 3	−18	15	−10	.....	.....	
14	− 6	−20	14	−13	.....	.....	
15	0	−17	17	− 1	.7	.....	
16	41	− 3	44	6	.5	.....	
17	32	− 5	37	28	.....	.....	
18	41	21	20	26	[a] T.	.....	
19	34	14	20	30	.....	.....	
20	41	28	13	40	.....	.....	
21	40	22	18	31	.....	.....	
22	34	31	3	33	.....	.....	
23	34	15	19	25	.....	.....	
24	34	18	16	27	.....	.....	
25	37	9	28	29	.....	.....	
26	36	19	17	29	.....	.....	
27	44	20	24	38	.....	.....	
28	37	3	34	12	.....	.....	
29	15	− 5	20	− 5	.....	.....	
30	12	−15	27	5	.....	.....	
31	38	4	34	26	.....	.....	
Sum	574	−82	.....	.....	2.7	.....	
Mean	18.5	−2.6	.....	.....	.....	.....	

REMARKS.

Chinook on the 16th.

High winds on the 4th, 5th, 9th, 14th, 15th, 16th, 17th, and 18th of the month.

[a] T.=trace.

January, 1909, was the coldest month of a winter of normal temperature (13.8° F. for December, January, and February), during which all strains of alfalfa, including the very hardiest, winterkilled, from a few per cent to 100 per cent. January, 1907, on the other hand, was the coldest month of a winter of extraordinary severity, through which some plants of all strains, including the very tenderest, passed uninjured.

An inspection of Table XII shows that for a period of two weeks, extending from the 4th to the 17th of the month, the minimum temperature fell from −3° to −31° F. daily, while during one week of this period the maximum did not rise above −6° F. The snowfall for the month was light, amounting to 2.7 inches. There were seven or eight days with high winds, so that the small amount of snow that fell did not remain in place except where there was something adequate in the way of a plant covering to hold it. As a

result of these winds the alfalfas had practically no snow to protect them.

A chinook, a climatic factor that is sometimes very trying to perennial crops and winter grains in this section, occurred on the 16th of the month. On this date the mercury rose rapidly from −3° to 41° F., a range of 44 degrees for the day.

The mean temperature for January, 1909, 7.8° F., was almost 12 degrees higher than that for January, 1907, −3.9° F., and a trifle more than 3 degrees lower than the normal for sixteen years. Hence, while this month was considerably warmer than the same month in 1907, it was nevertheless colder than the average, and, considering other climatic conditions, furnished a splendid test of the hardiness of alfalfa. The mean temperatures of February and March, 1909, were higher than usual, as may be seen by an inspection of Table IV. From February 7 to 15 the minimum temperatures ranged from −9° F. on the 7th to −25° F. on the 14th. Fortunately for the plants a snowfall of 5 inches occurred between these dates. No severe winds to blow the snow into drifts were noted.

March weather was much less trying than that of 1907 and 1908. In 1907 the range for this month was from −8° to 69° F.; in 1908, from −17° to 54° F.; while in 1909 the lowest temperature was 7° F. and the highest 58° F.

EFFECT OF WINTER OF 1908–9 ON ALFALFA VARIETIES.

The spring awakening in those strains that endured the winter with any marked degree of success came about the usual time, beginning with the middle of April. In many strains whose mortality was high those plants that survived did not begin growing until a month later.

In order to make possible an accurate comparison of the resistance to cold of the sixty-eight strains used in the 1908–9 experiments, Table XIII is presented.

TABLE XIII.—*Results of experiments, showing the dead and living plants of alfalfa varieties sown in drill rows and hill rows, and the percentage of plants winterkilled at Dickinson, N. Dak., during the winter of 1908–9.*

Row No.	Number.	Source.	Drill rows.				Hill rows.				Combined proportion of winterkilling.
			Dead plants.	Living plants.	Total.	Winterkilled.	Dead plants.	Living plants.	Total.	Winterkilled.	
			Number.	*Number.*	*Number.*	*Per cent.*	*Number.*	*Number.*	*Number.*	*Per cent.*	*Per cent.*
1	S. P. I. 21829	Deseret, Utah (second crop irrigated)	56	7	63	88.9	25	.....	25	100.0	92.0
2	S. P. I. 21232	Mongolia (bulk lot)	14	46	60	23.3	6	19	25	24.0	23.5
3	P. L. H. 2124	Mongolia (large seed)	25	31	56	44.6	8	17	25	32.0	40.7
4	P. L. H. 2125	Mongolia (medium-sized seed)	23	35	58	39.6	8	17	25	32.0	37.3
5	S. P. I. 12784	Emery, Utah	46	10	56	82.1	23	2	25	92.0	85.2
6	S. P. I. 18627	Arabia	58	.....	58	100.0	25	.....	25	100.0	100.0
7	S. P. I. 18628	.....do	51	.....	51	100.0	25	.....	25	100.0	100.0
8	S. P. I. 21768	.....do	69	.....	69	100.0	25	.....	25	100.0	100.0
9	S. P. I. 21769	.....do	63	.....	63	100.0	25	.....	25	100.0	100.0
10	S. P. I. 21828	Deseret, Utah (first crop irrigated)	52	7	59	88.1	24	1	25	96.0	90.5
11	P. L. H. 3260	Yuma-Peruvian (second crop)	62	.....	62	100.0	25	.....	25	100.0	100.0
12	S. P. I. 13237	Chinook, Mont	57	11	68	83.8	18	6	24	75.0	81.5
13	S. P. I. 14972	Guaranda, Ecuador	57	.....	57	100.0	25	.....	25	100.0	100.0
14	S. P. I. 3507	Buenos Aires, Argentina	62	1	63	98.4	25	.....	25	100.0	98.9
15	S. P. I. 3508	Mendoza, Argentina	55	.....	55	100.0	23	.....	23	100.0	100.0
16	S. P. I. 12549	Buenos Aires, Argentina	67	1	68	98.5	25	.....	25	100.0	98.9
17	P. L. H. 3321	Baden, Germany	41	20	61	67.2	23	1	24	95.8	75.3
18	S. P. I. 9322	Tuggurt, Algeria	58	.....	58	100.0	25	.....	25	100.0	100.0
19	S. P. I. 12409	Diamond Fork, Utah (nonirrigated)	61	1	62	98.5	23	2	25	92.0	96.6
20	S. P. I. 12846	Kebilli, Tunis	62	.....	62	100.0	25	.....	25	100.0	100.0
21	S. P. I. 17992	Valencia, Spain	63	.....	63	100.0	23	.....	23	100.0	100.0
22	S. P. I. 21867	Nephi, Utah (dry land)	55	4	59	93.2	25	.....	25	100.0	95.2
23	S. P. I. 12694	Provence, France	61	.....	61	100.0	25	.....	25	100.0	100.0
24	S. P. I. 12695	Poitou, France	59	.....	59	100.0	21	4	25	84.0	95.2
25	S. P. I. 21195	Provence, France	59	.....	59	100.0	25	.....	25	100.0	100.0
26	S. P. I. 13259	Milburn, Nebr	49	10	59	83.1	23	1	24	95.8	86.7
27	S. P. I. 13857	Simbirsk, Russia	34	9	43	79.1	15	4	19	78.9	79.0
28	S. P. I. 991	Tashkend, Turkestan	43	4	47	91.5	15	2	17	88.2	90.6
29	S. P. I. 9359	Erivan, Russia	43	.....	43	100.0	12	7	19	63.1	88.7
30	S. P. I. 9450	Askhabad, Turkestan	23	1	24	95.8	18	4	22	86.4	89.1
31	S. P. I. 9452	Karabulak, Turkestan	29	12	41	70.7	16	9	25	64.0	68.2
32	S. P. I. 9453	Bokhara, Turkestan	30	27	57	52.6	16	9	25	64.0	56.1
33	S. P. I. 13999	Tashkend, Turkestan	51	1	52	98.1	24	.....	24	100.0	98.7
34	S. P. I. 14786	.....do	41	12	53	77.3	19	6	25	76.0	77.0

35	S. P. I.	18425	Commercial Turkestan	39	4	43	90.7	16	.....	16	100.0	93.2
36	S. P. I.	18751	.....do	15	29	44	34.1	22	2	24	91.7	54.4
37	S. P. I.	19968	Samarkand, Turkestan	18	16	34	52.9	18	4	22	81.8	64.3
38	S. P. I.	20437	Tashkend, Turkestan	45	8	53	84.9	24	.....	24	100.0	89.6
39	S. P. I.	21032	Commercial Turkestan	13	34	47	27.7	13	12	25	52.0	36.1
40	P. L. H.	3252	South Dakota (Tashkend, Turkestan)	1	49	50	2.0	6	19	25	24.0	9.2
41	S. P. I.	12747	Billings, Mont	14	32	46	30.4	17	8	25	68.0	43.7
42	S. P. I.	13436	Canada	14	40	54	25.9	17	8	25	68.0	39.2
43	S. P. I.	21247	.....do	16	22	38	42.1	16	8	24	66.7	51.6
44	S. P. I.	11651	Pueblo, Mexico	35	5	40	87.5	19	3	22	86.4	89.1
45	S. P. I.	11652	Guanajuata, Mexico	30	9	39	76.9	21	3	24	87.5	80.9
46	S. P. I.	11275	Commercial (bought in Chicago)	34	14	48	70.8	24	1	25	96.0	79.4
47	S. P. I.	12398	Fort Collins, Colo	40	7	47	85.1	22	3	25	88.0	86.1
48	S. P. I.	12671	Lawrence, Kans	35	6	41	85.4	21	4	25	84.0	84.8
49	S. P. I.	12816	Chinook, Mont	35	19	54	64.8	21	4	25	84.0	70.9
50	S. P. I.	12820	Clearwater, Nebr	32	18	50	64.0	18	7	25	72.0	66.7
51	S. P. I.	21938	Excelsior, Minn. (Grimm)	4	42	46	8.7	1	24	25	4.0	7.0
52	P. L. H.	3235	Fargo, N. Dak. (Grimm)	1	46	47	2.1	1	22	23	4.3	2.8
53	S. P. I.	21945	Sextorp, Nebr. (dry land)	36	13	49	73.5	20	5	25	80.0	75.7
54	P. L. H.	3251	Highmore, S. Dak. (Baltic)	18	35	53	34.0	9	16	25	36.0	34.6
55	P. L. H.	3255	Nephi, Utah (dry land)	44	10	54	81.5	23	2	25	92.0	84.8
56	P. L. H.	3256	.....do	50	7	57	87.7	21	4	25	84.0	86.6
57	S. P. I.	21187	France (commercial sand lucern)	32	24	56	57.1	19	6	25	76.0	63.0
58	S. P. I.	21217	Germany (commercial sand lucern)	30	22	52	57.7	21	3	24	87.5	67.1
59	S. P. I.	21269	.....do	43	7	50	86.0	23	2	25	92.0	88.0
60	S. P. I.	20896	France (commercial sand lucern)	50	6	56	89.3	20	2	22	90.9	89.7
61	S. P. I.	22416	Piedmont, Italy	51	.....	51	100.0	24	1	25	96.0	98.9
62	S. P. I.	22417	Germany (Provence strain)	56	1	57	98.2	25	.....	25	100.0	98.8
63	S. P. I.	22418	Germany (commercial sand lucern)	50	7	57	87.7	21	4	25	84.0	86.6
64	S. P. I.	22558	Gunnison, Utah (irrigated)	49	8	57	85.9	24	1	25	96.0	89.0
65	S. P. I.	22559	Gunnison, Utah (dry land)	41	4	45	91.1	25	.....	25	100.0	94.3
66	S. P. I.	12803	Setif, Algeria	40	16	56	71.4	24	1	25	96.0	79.0
67	S. P. I.	20988	Commercial Turkestan	17	37	54	31.5	23	2	25	92.0	50.6
68	P. L. H.	3346	Richardton, N. Dak	31	6	37	83.8	25	.....	25	100.0	90.3

The thirty-four varieties named in the first half of this table, comprising the east section of the nursery, are shown in Plate I, figure 2 (frontispiece), just back of the middle-ground. The photograph was taken June 10, 1909. Row No. 1 is designated by the white stake to the left of the figure 1 in the plate, and extends from this stake to the one next to the figure 35. The latter designates the row of this number. The stake labels stand at the head of the rows, or east end, while the photograph was taken from the foot of the rows of the west section, which comprises the varieties shown in the second part of Table XIII. The stakes scattered about in both the east and west sections indicate plants that were marked in the autumn of 1908 for work in selection and studies in correlation. The stakes appearing beyond the row from 1 to 34 are in another section of the nursery started in 1909, which is not a part of the present discussion.

In September, 1908, the number of living plants in both the hill and drill rows was determined by actual count. This count was made with very great care, and no row was left until the person counting was certain of the correctness of the count. On June 15 another count was made of the living and the dead plants in all rows and this was compared with the count of the previous autumn. In this way the percentage of winterkilling for the various strains was secured, as shown in Table XIII.

The loss of the sixty-eight strains may be summarized as follows:

12 strains killed out, 100 per cent.
16 strains killed out, 90 to 99 per cent.
14 strains killed out, 80 to 90 per cent.
7 strains killed out, 70 to 80 per cent.
5 strains killed out, 60 to 70 per cent.
4 strains killed out, 50 to 60 per cent.
2 strains killed out, 40 to 50 per cent.
4 strains killed out, 30 to 40 per cent.
1 strain killed out, 20 to 30 per cent.
2 strains killed out, 5 to 10 per cent.
1 strain killed out, 1 to 5 per cent.

For the sake of convenience the winter resistance of the strains under experiment will be taken up on the basis of their immediate geographical origin, as shown in Table IX, although this may lead in some cases to combining in one group several things that differ materially, both physiologically and botanically.

WINTER RESISTANCE OF ALFALFAS IN DRILL ROWS AND HILLS IN THE 1908–9 EXPERIMENTS.

Alfalfas from South America.

Five alfalfas from South America showed an average mortality of 99.6 per cent. These strains were known to be nonhardy but were included in the experiment for purposes of comparison. The Peruvian, P. I. H. No. 3260, which lost 100 per cent, was grown at Yuma, Ariz., from the original S. P. I. No. 9303, described in Bulletin 118 of this Bureau. By reference to Table I it will be seen that 1 and 5 per cent of No. 9303 endured the severe winter of 1906–7 at Dickinson. This same strain suffered a loss of only 12.8 per cent of its stand at Stockton, Kans., during the winter of 1908–9.

The strain from Ecuador is the famous Guaranda alfalfa, a short account of which also occurs in the bulletin cited. It is practically identical with the Peruvian and was completely killed out at Dickinson, N. Dak., while at Stockton, Kans., the average loss of two Guaranda samples was 10.6 per cent.

The Argentine samples resemble the foregoing in some respects, but on the whole their affinities are more strongly toward the Chilean type represented by our own Utah and California sort.

Alfalfas from Africa.

Rows 18 and 20 (S. P. I. Nos. 9322 and 12846, respectively), which killed out 100 per cent, are the highly prized Oasis alfalfa of the Sahara. The tenderness to cold of the Oasis variety will confine its usefulness to the warmer parts of the Southwest, where it is of promise because of the fine quality of its hay. It winterkills severely as far south as Kansas, as may be seen from Plate II, figure 2, which is more fully described later in discussing the strain from Arabia. The photograph used for this illustration was taken on the farm of Mr. E. Bartholomew, near Stockton, Kans. The experiments there, as well as those at Dickinson, showed that merely living through the winter is not a sufficient recommendation for the use of a certain strain of seed. The variety must be so hardy that it will emerge from winter fit to take advantage of the first growing temperatures of spring. Nonhardy individuals of Oasis alfalfa No. 12846, the row shown in the middle of the picture, severely injured by the mild winter, did not recover sufficiently to begin a visible growth until a month later than the more resistant individuals. Of this strain 51.5 per cent killed out at Stockton and 100 per cent at Dickinson. No. 9322 did not suffer as severely in comparison, losing 35.2 per cent at Stockton, while at the northern station its loss was also 100 per cent.

The third North African strain (S. P. I. No. 12803, row 66) is the one grown in rows at Setif, Algeria, and referred to in a preceding footnote (pp. 9–10) of this paper. Seventy-nine per cent of the plants of this variety, which appears very similar to the Poitou alfalfa of France, winterkilled. The average number of plants winterkilled for the three African strains at Dickinson was 93 per cent.

Alfalfas from Europe.

There were included in the experiment 15 samples from European sources. The average loss of plants for all strains was 87.9 per cent.

	Per cent.
2 Russian strains lost an average of	83. 9
5 German strains lost an average of	83. 1
5 French strains lost an average of	89. 6
1 Italian strain lost	98. 7
1 Spanish strain lost	100
1 commercial strain lost	79. 5

One of the German strains (row 17, P. L. H. No. 3321, which occurs in the inventories of the Office of Foreign Seed and Plant Introduction under Nos. 22467 [a] and 24767 [b]) is of sufficient interest to deserve a preliminary note in the present connection. This strain is known as "alt-deutsche fränkische Luzerne," and all evidence thus far secured points to its being the progenitor of the highly esteemed Grimm alfalfa, which is mentioned later in these pages. It takes its name from the circles of Franconia in northern Bavaria, and the present sample was secured only a few miles from the ancestral home of Wendelin Grimm, who introduced alfalfa into Minnesota in 1857. It is interesting to note that this strain has the same distinctive habit of growth as the Grimm.

The appearance of a majority of the rows of European alfalfa, or lucern, after the winter of 1908–9 is shown in Plate III, figure 1. The old German variety previously mentioned is row 17 and can be seen best in Plate I, figure 2 (frontispiece). It forms the continuation of the right-hand row of Grimm alfalfa near the center of the picture. Row 46 (S. P. I. No. 11275), a commercial sample purchased in the open market, appeared from its botanical characteristics to be of European origin. The seedsmen who furnished it state that it was purchased from an Italian source. This number suffered to the extent of 79.5 per cent. It resembles strongly S. P. I. No. 12803 from Setif, Algeria (row 66).

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[a] See "Seeds and Plants Imported during the Period from January 1 to March 31, 1908," Bulletin 137, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, pp. 56–57.

[b] See "Seeds and Plants Imported during the Period from January 1 to March 1, 1909," Bulletin 162, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 42.

Alfalfas from Asiatic Sources.

ARABIA.

The discussion of the strains from Asia falls naturally into three groups. Taking up first the Arabian strains, rows 6, 7, 8, and 9, their loss was 100 per cent for each of the four numbers. As far south as Stockton, Kans., these same numbers killed out 100 per cent, though the winter there was an extremely mild one. The condition of these rows at Stockton on June 1 is shown in Plate II, figure 2. The two rows in the middle of the picture showing a certain percentage of living plants are African strains, the one having the better stand being identical with Dickinson row 20, Kebilli Oasis alfalfa (S. P. I. No. 12846), while the other is from Tripoli (S. P. I. No. 12847). The pairs of rows on either side are the Arabian numbers.

TURKESTAN.

Among the twelve strains listed as from Turkestan three were produced in the United States from Turkestan seed of known origin. S. P. I. No. 13999 (row 33) was grown on unirrigated land in Utah in 1904 from S. P. I. No. 991 (see row 28), which was sown in 1900; S. P. I. No. 19968 (row 37) was grown in Kansas in 1906 from S. P. I. No. 1295, from Samarkand, sown in 1899. S. P. I. No. 20437 (row 38) was produced in 1906 by the same field as No. 13999, noted above. The average loss in stand of these three numbers was 84.3 per cent.

Inasmuch as practically all of the Turkestan seed used by American farmers comes from a great range of unknown conditions of soil and climate under the commercial name "Turkestan," four samples purchased in the open market were included in the experiment. These samples are rows 35, 36, 39, and 67. The average winterkilling of the strains was fairly low, 58.6 per cent, but the range was from almost 36 per cent (row 39) to almost 93 per cent (row 35). When one considers that Turkestan has an area almost as great as that part of the United States lying west of the Mississippi and a climate that ranges from as cold as Montana to as hot as Arizona, this range in the hardiness of commercial samples of seed is not surprising. It suggests also the danger confronting the northern grower who purchases seed whose only recommendation is that it came from Turkestan.

The last class of Turkestan strains includes five secured from known sources. These came from a considerable range of territory, extending from Askhabad, in the southern part of the Transcaspian district, northeastward through Bokhara and Tashkend and northwest to Karabulak, north of the Aral Sea. It is a matter of regret that no sample from Verni, which is said to be the coldest alfalfa-producing section of Turkestan, was included in this experiment. In the new

experiments begun during the spring of 1909 a sample of Verni or Tschilik alfalfa has been included.

The average winter injury to five strains of known origin amounted to 76.2 per cent, the range being from a little more than 56 per cent (row 32) to almost 91 per cent (row 28).

The average winterkilling of Turkestan strains may be summarized as follows:

	Per cent.
Commercial strains (4)	58.6
Strains from known sources (5)	76.2
American-grown strains (3)	84.2
Average for all strains	72.3
Average for imported strains (commercial and known sources combined)	68.3

It is apparent from the foregoing and from Table XIII that while none of the Turkestan strains in their present condition are hardy enough for the cold Northwest, several of them are promising for acclimatization by selective breeding methods.

One American-grown strain of Turkestan alfalfa, South Dakota No. 240 (P. L. H. No. 3252, row 40), has been assigned to South Dakota and has not been discussed here. This variety was secured through Prof. W. A. Wheeler and is the progeny of S. P. I. No. 991 (see row 28, Table XIII), the original importation of Turkestan alfalfa introduced in 1898 by Prof. N. E. Hansen. A plat of No. 991 was seeded at the Highmore branch of the South Dakota station in the spring of 1899. The seed used at Dickinson was produced on this plat in 1906, the seventh year after seeding. A comparison of rows 28 and 40, Table XIII, shows that the parent strain, No. 991, lost 58 of 64 plants, while its progeny grown in South Dakota lost only 7 out of a total of 75 plants. Rows 33 (S. P. I. No. 13999) and 38 (S. P. I. No. 20437) are also the progeny of No. 991. Some further discussion of these strains will be given later.

MONGOLIA.

The three rows of Mongolian alfalfa were all secured from the same importation. P. L. H. Nos. 2124, row 3, and 2125, row 4, were selected from the bulk lot, S. P. I. No. 21232, row 2, on the basis of color and size of seed. No. 2124 comprised the largest seed contained in the original lot. It was of rose-purple color, unusually large size, and fairly good germination, 85.5 per cent. No. 2125 was somewhat smaller than the former, but considerably larger than the remainder of the bulk lot and of the typical greenish color of alfalfa seed. No. 21232 was the original sample, noted above, with the large seed removed.

The average winterkilling of these three samples was 33.5 per cent. The average for the two seed selections was 39 per cent, the loss being greatest for the larger seed. It would not be safe to assume from this that size of seed is correlated with hardiness. Nevertheless, the facts are of interest, especially as the Arabian and Peruvian varieties which are the tenderest alfalfas known also have the largest seeds.

The bulk lot containing the smaller-sized seed suffered only to the extent of 23.5 per cent, showing the lowest percentage of loss among all of the many imported samples included in the experiment.

This interesting and valuable alfalfa was secured in 1907 by the Office of Foreign Seed and Plant Introduction through Hon. W. W. Rockhill, American Minister to the Chinese Empire, on the basis of a memorandum presented by Mr. Walter T. Swingle, Physiologist in Charge of Crop Physiology and Breeding Investigations. Mr. Swingle, in the course of his studies of Chinese agriculture, found an account of a French missionary,[a] written over forty years ago, of the growing of alfalfa in Mongolia. This led to further investigation and to the ultimate securing of the seed from the Belgian missionaries stationed in the region. The seed came from the high and relatively cold Ordos country, where it has probably been grown for centuries. Rows 2, 3, and 4 in Plate III, figure 2, show the excellent condition of this variety in the summer of 1909.

Alfalfas from North American Sources.

Of the alfalfas from North America, two came from Canada, two from Mexico, and twenty-two from the United States.

CANADA.

Two Canadian strains, purchased in the open market, whose exact origin is unknown to the writers, showed a promising degree of hardiness. Their average loss was 45.4 per cent. The hardier of the two, which suffered only to the extent of 39.24 per cent, was secured in Canada in 1904 by what was then the Office of Grass and Forage-Plant Investigations.

It is apparent from the botanical characters of these strains (S. P. I. Nos. 13436, row 42, and 21247, row 43) that they are of European origin, a fact to which attention was first directed by Mr. J. M. Westgate, of the Bureau of Plant Industry.

An examination of rows 42 and 43 in Plate IV, figure 1, shows the appearance of the Canadian alfalfa after the winter, as compared with other American strains surrounding it.

[a] David, Père A., in Flore des Serres et des Jardins de l'Europe, vol. 18, pp. 124 and 126, 1869–70 (Extracts from a letter to M. Decaisne).

MEXICO.

The average winterkilling of the Mexican rows 44 and 45 (S. P. I. Nos. 11651 and 11652) was 85 per cent. The original source of these strains is unknown, but their immediate geographical origin would have led one to expect a higher percentage of loss. Rows 44 and 45 are shown in Plate IV, figure 1, next to the Canadian numbers. In habit of growth, leafage, etc., they resembled considerably some of the Turkestan strains.

UNITED STATES.

Among the strains attributed to this country two classes must be recognized: (1) Those that are without doubt ordinary American alfalfas of the Chilean type, of which there are eighteen numbers, and (2) those that are clearly the progeny of introductions from the Old World. Of the latter there are only four (rows 40, 51, 52, and 54), but among them are the alfalfas of the greatest present importance to agriculture in the cold parts of the United States.

Ordinary American Alfalfa.—Ordinary American alfalfa, which came to the United States from Chile, has often proved not sufficiently hardy for our severe northern climate. The average winterkilling of the eighteen strains included under this head was 83.3 per cent. The greatest mortality is found in three of the Utah dry-land strains, as follows:

	Per cent.
Row 19, S. P. I. No. 12409, Diamond Fork, Utah	96.6
Row 22, S. P. I. No. 21867, Nephi, Utah	95.2
Row 65, S. P. I. No. 22559, Gunnison, Utah	94.3
Average	95.4

The hardiest strain of ordinary American alfalfa was a Montana strain (row 41, S. P. I. No. 12747). This seed was produced in the Yellowstone Valley near Billings, where it had been grown for a number of years. This sample suffered to the extent of 43.7 per cent.

Next to the above in hardiness was the sample from Clearwater in north-central Nebraska, row 50, S. P. I. No. 12820. This number suffered to the extent of 66.7 per cent. These and several other American strains are shown in Plate IV, figure 1 (rows 41, 47, 48, 49, and 50).

Only two other strains of this class showed a degree of hardiness that entitles them to mention. These strains and the proportion of the plants winterkilled are as follows:

	Per cent.
Row 49, S. P. I. No. 12816, Chinook, Mont	70.9
Row 53, S. P. I. No. 21945, Sextorp, Nebr	75.7

The latter is a highly esteemed dry-land form grown by Mr. Lewis Brott on the high plains of western Nebraska. Unlike the Utah dry-

land strains this one is grown in a section that is subject to decidedly low temperatures at times, with little or no snow covering to protect plant growth. The normal autumn rainfall in this section is very light.

The question whether American alfalfa of the ordinary sort has undergone any change in hardiness since its introduction, about 1855, has been discussed recently by alfalfa breeders and growers. No experimental evidence bearing on the point has been published heretofore. Hence, the results obtained in the present experiment while by no means conclusive are of more than ordinary interest.

The eighteen strains of ordinary American alfalfa showed a great difference in hardiness, as winterkilling under the uniform conditions of the experiment ranged from about 44 per cent (row 41) to almost 97 per cent (row 19). The mere presence of so high a degree of diversity with reference to one physiological character is extremely suggestive.

Botanically, alfalfa or lucern (*Medicago sativa*) is an exceedingly diverse species composed of numerous strains, varieties, or possibly subspecies. Even the most uniform of our cultivated sorts, such as the Peruvian and Arabian, comprise numerous strains that are easily recognizable on inspection. Ordinary alfalfa, of course, shares in the diversity common to the species as a whole. That some of these component lines or individuals are more susceptible to cold than others seems axiomatic. Resistance to cold would then depend largely at least on the severity of the climate to which a strain has been subjected; that is, to the amount of "weeding out" of unfit lines and individuals that has taken place.

The selective value of the Montana climate with reference to hardiness is unquestionably greater than that of Utah or most of Nebraska; in fact, it does not seem unfair to suppose that that of northern Nebraska is superior to that of Kansas.

Different winters have different selective or acclimatizational values with reference to various test factors. Very severe winters with heavy snows that remain in place have small selective effect; mild winters with even a moderate snowfall, such as that of 1907–8 at Dickinson, have practically no effect on strains having only the customary degree of hardiness. Tender sorts, like the Arabian, Peruvian, Tunisian, and Tripolitan, are susceptible of selection with even comparatively mild winters, such as that of 1908–9 at Stockton, Kans.

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The following statement shows by States the average winterkilling of common alfalfa in the row and hill experiments at Dickinson:

	Strains.	Per cent.
Utah	[a] 10	90.4
Colorado	1	86.1
Kansas	1	84.8
Nebraska	3	76.4
Montana	3	65.4

The number of strains from the different States is too small to use as a basis for generalization, but it is hoped that the data here given will lead other investigators to make a careful record of results of similar experiments.

Progeny of Old World Introductions.—It is among the progeny of alfalfas introduced from the Old World that we find the highest degree of hardiness, a degree of hardiness that in at least one case might almost be called wonderful.

Each of the four numbers included in this class emerged from the winter of 1908–9 with a notably high percentage of living plants. Their combined average loss is 13.5 per cent, while the percentages of loss for the individual strains were as follows:

Table XIV.—*Results of experiments showing the percentage of winterkilled alfalfa plants of four strains introduced from the Old World.*

Row No.	Accession No.	Source.	Proportion of winterkilled plants.
			Per cent.
52	P. L. H. 3235..	Fargo, N. Dak. (Grimm) (originally from Baden, Germany)	2.8
51	S. P. I. 21938..	Clearwater, Minn. (Grimm) (originally from Baden, Germany)	7.0
40	P. L. H. 3252..	Highmore, S. Dak. (originally from Tashkend, Turkestan) (S. Dak. No. 240).	9.2
54	P. L. H. 3251..	Brookings, S. Dak. (S. Dak. No. 167. Original source not known, but probably from Europe).	34.6
		Average	13.4

Grimm alfalfa.[b]—Grimm alfalfa, which is named after Wendelin Grimm, the German immigrant by whom it was introduced, is the hardiest form of the cultivated plant known at the present time. Its progenitor was brought to Minnesota in 1857 from Külsheim, between Wertheim and Tauberbischofsheim, in the valley of the Tauber of Baden, Germany.

[a] This includes row 18, common alfalfa which endured the mild winter of 1907–8 in North Dakota.

[b] A short account of the history and probable method of development of Grimm alfalfa by the senior writer of this bulletin has been published, entitled "The Acclimatization of an Alfalfa Variety in Minnesota," Science, n. s., vol. 28, December, 1908, pp. 891–892.

The drainage basin of this little stream, which empties into the Main at Wertheim, known as the Taubergrund, is at the present time the chief seat of the production of seed of "alt-deutsche fränkische Luzerne" (row 17), already mentioned in these pages. This strain of alfalfa is highly prized in Germany and appears to have been under cultivation in the old Franconian circles of Baden, Württemberg, and Bavaria for several hundred years.

The two Grimm strains included in the present experiment proved to be the hardiest of the sixty-eight under observation. The hardier one, P. L. H. No. 3235 (row 52), was produced in 1904 on a plat about 4 years old on the farm of the North Dakota experiment station. This seed was presented to the Department of Agriculture in October, 1904, by Prof. J. H. Shepperd, vice-director and agriculturist. This strain lost less than 3 per cent of the plants in hill and drill rows combined. Only one plant of twenty-five in the hills, which are $2\frac{1}{2}$ feet apart in the row with the rows themselves 3 feet apart, succumbed during the winter. In the 50-foot drill row only one plant out of forty-seven was killed.

Second in hardiness was a Minnesota-grown strain of Grimm alfalfa, S. P. I. No. 21938 (row 51). This seed was secured from Mr. A. B. Lyman, of Excelsior, Minn. It was produced near Clearwater, Stearns County, from Carver County seed. In the hill row one plant in twenty-five winterkilled, in the drill row four out of forty-six, the average loss for both being 7 per cent.

As an indication of the vigor that the Grimm alfalfa had after passing through the winter of 1908–9, which was so destructive to ordinary alfalfas, mention may be made of the yield of seed from a tenth-acre plat of Grimm grown just adjacent to the experiment under consideration. This plat was sown in the spring of 1908 in rows 3 feet apart and kept cultivated. The plants were quite thick in the row. A clipping was made of this plat in 1909 early in the season, when it had attained a growth of about 8 inches. It was not cut again until September 28, when a cutting was made for seed. The plat yielded 33.6 pounds of clean seed, which is at the rate of 336 pounds, or 5.6 bushels, per acre. This is certainly an admirable showing.

If, as appears likely, the old German Franconian lucern (row 17) is the progenitor of the Grimm, we have here a further suggestion as to the possibilities of habituating alfalfa to a new or foreign climate. The loss of the former was over 75 per cent, the average for two strains of Grimm less than 5 per cent.

Acclimatized Turkestan alfalfa.—Plant Life History No. 3252, row 40 (S. Dak. No. 240), was produced at Highmore, S. Dak., by Prof. W. A. Wheeler, from Prof. N. E. Hansen's original introduction of

Turkestan alfalfa from Tashkend (see row 28), S. P. I. No. 991. In Bulletin 101[a] of the South Dakota Agricultural Experiment Station Professor Wheeler has given a short account of this strain, a part of which is as follows:

No. 240. Seed was obtained from the United States Department of Agriculture under S. P. I. No. 991. This was collected (obtained) by Prof. N. E. Hansen at Tashkend; Turkestan, in 1898. It has been grown in plots at Highmore since 1899 and apparently has not killed out. This is a severe test of its resistance to both cold and drought. A small plot has been cut for seed in both 1905 and 1906 and some seed has been obtained. So far, it does not appear to be nearly as good a seed producer as any of Nos. 162,[b] 164,[c] or 167,[d] but it can not be compared with these until it has gone through as many generations from seed in this State as have the other three numbers cited. This alfalfa is thought to be of the same introduction as No. 164. If this is correct it will probably become a better seed producer after it has been grown from several seed-producing generations in this State. The quality of this number is about the same as No. 164. This ranks as one of the four best alfalfas which have been tried at Highmore.

Numbers 162, 164, 167, and 240 are hardy and are possessed of high forage qualities, so that they can be recommended for the conditions under which they have been tried. Numbers 162 and 167 start earlier in the spring and produce a stronger and more vigorous first crop than numbers 164 and 240. With the second crop this difference is not so noticeable. These four numbers have been tested from eight to ten years in this State and with the exception of number 240 have gone through several generations from seed. The fact that they have reproduced from seed through several generations seems to have more to do with acclimating alfalfa than has the mere fact that they have grown so many years under these conditions from a single seeding. This is where No. 164 leads over No. 240. * * *

For the present the work will be restricted entirely to selected stocks from Nos. 162, 164, and 167. Work with No. 240 progresses more slowly because of its poorer seed production.

An examination of the published station records shows that although No. 240 has been grown at Highmore since 1899, even approximately accurate data concerning its behavior have been taken only since 1903.

The seed used in the Dickinson experiments was produced in 1905, the seventh year from seeding. This acclimatized Turkestan strain ranked third in hardiness among the sixty-eight strains tested, and appears to show that the parent strain had become profoundly changed in cold endurance by the seven winters spent in South Dakota. This change probably resulted from the successive eliminations of the unfit lines of descent.

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[a] Wheeler, W. A., and Balz, Sylvester. Forage Plants at the Highmore Substation, 1906. Bulletin 101, South Dakota Agricultural Experiment Station. March, 1907.

[b] This number is the Grimm alfalfa of Minnesota, grown for several years at Brookings and Highmore.

[c] No. 164 is supposed to be the progeny of the same number (S. P. I. No. 991) as the present sample, P. L. H. No. 3252. No. 164 was produced from No. 991 sown at Brookings in 1898, while No. 240 was produced from No. 991 sown at Highmore in 1899.

[d] No. 167 is the parent of P. L. H. No. 3251 (row 54 at Dickinson).

This strain of Turkestan alfalfa which underwent seven years natural selection in South Dakota presents an opportunity for several important comparisons. These are not presented as final in any sense, but rather to stimulate further investigation.

Row 28 was seeded with a small quantity of seed remaining from the original lot of S. P. I. No. 991, the first importation from Turkestan. Row 40 is the South Dakota progeny of No. 991. Rows 33 and 38 are the Utah progeny of the same number. Both were harvested from the same field which was seeded down in 1900. Row 33 was harvested in 1904, row 38 in 1906.

Table XV shows the comparative winter resistance at Dickinson of No. 991 and its Utah and South Dakota progeny.

TABLE XV.—*Comparison of Turkestan alfalfa, S. P. I. No. 991, with certain strains grown from it, showing the percentage of plants winterkilled.*

Row No.	Accession No.	Source.	Proportion of plants winterkilled.
			Per cent.
28	S. P. I. 991	Turkestan (imported 1898)	90.6
40	P. L. H. 3252	Highmore, S. Dak. (1899–1906)	9.2
38	S. P. I. 20437	Wellsville, Utah (1900–1906)	89.6
33	S. P. I. 13999	Wellsville, Utah (1900–1904)	98.7

The distance between row 28, the original stock, and row 33, the 1904 progeny, is only 15 feet, while that between rows 38 and 40 is only 6 feet. All conditions were uniform so far as known, and still this great diversity appears. The greater age of the original seed might be responsible for some of the difference in hardiness between this and the South Dakota-grown strain. But here we are confronted with the fact that the 1904 progeny from Utah—comparatively fresh seed—suffered even more than the foundation stock, while the 1906 crop suffered an almost equal loss. It is not possible in the limits of the present paper to discuss, nor is there sufficient data to warrant discussing, the numerous biologic factors that may be concerned in these diversities.

The differences in loss in the 1904 and 1906 Utah strains suggest that the two additional winters endured by the latter may have had greater selective value than those from 1900 to 1904. It appears from the records that this was the case. The lowest temperature that occurred during these years at Logan, Utah, the nearest point to Wellsville having a temperature record, was −17° F. on February 14, 1903; but on the 11th and 12th of the month more than 2 inches of snow had fallen, and the observer makes the comment that "fields were generally well covered with snow throughout the month, and it is therefore

not probable that any damage was done to fall grain by low temperatures."

The minimum temperature during the winters of 1904–5 and 1905–6 was −15° F., which occurred in both winters. The minimum of the former fell on February 12. Between January 1 and February 12 almost 2½ inches of rain had fallen. This no doubt resulted in a saturated condition of the soil that led to considerable injury to the plants when 15° F. below zero weather occurred on the 12th. January had been a warm, balmy month that tended to stimulate new growth in the plants.

The minimum temperature of the winter of 1905–6 (−15° F.) fell on January 8. Two inches of snow had fallen during the last days of December. This probably gave enough protection from the cold.

The seeding capacity of this strain, P. L. H. No. 3252, is not satisfactory according to Professor Wheeler; however, it is scarcely more than axiomatic to state that the seed production may be improved by the selection of those lines within the strain that produce seed better than the average of the strain. If we assume that the various lines within the strain remain constant from generation to generation, then we are not modifying the alfalfa in any other way when we improve its seed production. We are merely isolating those lines of high seed production. The strain is merely in the process of purification. On the other hand, it is not at all unlikely that mutations, of greater or less moment, are more or less constantly taking place within the strain. In such a case it would be quite proper to speak of the alfalfa as being modified, though such modifications would be almost purely spontaneous. In other words, we have not progressed enough in the science of breeding to be able to bring about desired mutations at will. The function of open pollination in alfalfa breeding is something about which we have almost no exact knowledge.

One difficulty in interpreting the results from the different sowings from No. 991 is that we are not well enough posted as to the previous history of the imported seed. The following statement concerning it is found in Inventory No. 1 of the Section of Seed and Plant Introduction:

991.[a] MEDICAGO SATIVA. **Alfalfa.**

From Tashkend. Received through Prof. N. E. Hansen, June 4, 1898. (200 bushels.)

Variety "*turkestanica*." This subspecies of alfalfa was obtained from eight different sources varying widely in climatic conditions. It endures droughts which kill European alfalfa. Deemed very promising for trial in droughty regions. See No. 469.

[a] Foreign Seeds and Plants Imported by the Section of Seed and Plant Introduction. Inventory No. 1, 1898, p. 81.

469.[a] MEDICAGO SATIVA. **Alfalfa.**

From Turkestan Agricultural Society, Turkestan. Received through Prof. N. E. Hansen, March, 1898.

Native alfalfa. Endures drought better than European alfalfa.

Rows 28, 38, and 33 run reasonably close together in hardiness. The deviation is perhaps no greater than would be expected from any run of commercial seed. Whether the seed from the eight original sources was mixed or not, a reasonable hypothesis would be that some of the hardier seed was planted in South Dakota. Even this seed was probably a mixture representing more or less hardy strains. By the result of natural selection the hardiest lines or strains were brought to the seeding stage in South Dakota and then transferred to Dickinson. It is an interesting fact that No. 991 was evidently imported more for its drought resistance than for any potential hardiness.

South Dakota No. 167.—Although the source from which the strain of seed, South Dakota No. 167, originally came is unknown, it is obvious from its botanical characteristics that it is of European origin.[b] The name Baltic was first applied to it in 1906 by Prof. W. A. Wheeler, formerly botanist to the South Dakota Agricultural College and Experiment Station, from the fact that it had been grown for about ten years near the little village of Baltic in Minnehaha County, S. Dak., and not as has been supposed in the Baltic Sea region of Europe.

The appearance of this strain, which is P. L. H. No. 3251, in the spring of 1909 is shown in Plate III, figure 1, row 54. Although showing a promising degree of hardiness, at Dickinson this strain was the tenderest of the four hardy American races derived from the Old World introductions. In the drill rows, where it is possible that the thicker stand by binding more snow may have been afforded slightly more protection, the loss was 34 per cent, while in the hill

[a] Op. cit., p. 42.

[b] Mr. J. M. Westgate, of the Office of Forage-Crop Investigations, first directed attention to the probable European origin of this alfalfa. Mr. Westgate noted the very interesting fact that several European alfalfas show greater diversity in flower color than do our ordinary American or the Turkestan types. In the Dickinson experiments the diversity is about equal in the Grimm samples (rows 51 and 52), South Dakota No. 167, the so-called Baltic alfalfa (row 54); "alt-deutsche fränkische Luzerne" (row 17); commercial or false sand lucern, No. 20896 (row 60); and first-quality commercial alfalfa, probably from Italy, No. 11275 (row 46). It occurs to a less degree in Simbirsk alfalfa, No. 13857 (row 27); in Poitou alfalfa, No. 12695 (row 24); Italian alfalfa, No. 22416 (row 61); and Algerian alfalfa, No. 12803, from Setif (row 66). At Stockton, Kans., a very similar degree of diversity in color was found in Italian alfalfas, Nos. 12696 and 13481. A much greater variegation in color was found to exist in commercial sand lucern, Nos. 21187, 21217, 21269, and 22418 (rows 57, 58, 59, and 63), though the last number showed less diversity than the other three.

rows, where the plants were subjected to the severest test, the loss was 36 per cent. It may be of interest to state that the entire nursery killed out 2.3 per cent more than did the plants in the drill rows.

Climatic conditions at Highmore, S. Dak. (altitude 1,860 feet), where the seed generation used in the present experiments was produced, are no doubt less severe than at Dickinson (altitude 2,453 feet), which is located about 300 miles farther northwest on the Great Plains. Professor Wheeler found the Baltic alfalfa very promising at both Highmore and Brookings and published his observations in Bulletin 101 of the South Dakota station, already cited. His notes are of sufficient interest to be quoted in full, as follows:

No. 167. The original source from which the seed of this number was introduced into this country is unknown. Mr. W. F. Kelly, of Renner, S. Dak., purchased the seed about ten years ago from a seed dealer at Hartford, S. Dak. He and Mr. E. C. Evans of the same place have grown it for about ten years and consider it better than other alfalfas tried in their vicinity. Mr. Kelly furnished several pounds of seed to the Agricultural College in 1905. A two years' trial of the variety is rather short upon which to draw conclusions. In all our tests, however, both at Highmore and Brookings, this number has shown itself equal to any in quality, hardiness, and seed production. It has not been sown in the selection rows and so has not been put to quite so severe a test of hardiness as No. 162 (Grimm alfalfa), and as there is no record of its having been tested under northern conditions in the past, as has No. 162, it can not be compared in hardiness to the latter number. In seed production it is equal if not superior to No. 162. In quality and the vigor of early spring growth it appears to be equal.

The test in the nursery rows at Dickinson was probably more severe than any this strain had previously endured. Hence, although not the equal of a few other strains it is decidedly valuable. It ranked fifth among the sixty-eight strains at Dickinson. Of the new introductions only one, Mongolian No. 21232, excelled it in winter resistance. It ranked high as a seed producer at Dickinson in 1909.

COMPARISON OF CONDITIONS IN FIELD PLATS AND IN ROWS AND HILLS.

The hill and row experiment just discussed represents the severest possible test of the winter resistance of alfalfa for the weather conditions that prevailed while the work was in progress. Fortunately, the two small series of field plats already discussed, which are on a rather pronounced southern slope above the alfalfa nursery, offer in comparison what might be termed decidedly more favorable conditions than alfalfa is likely to be grown under in most years in this region. Except for January the winter of 1908–9 was no more severe than may be expected any year.

One set of the field plats containing four different strains was seeded in the spring of 1907. These plats should have been cut in ordinary farm practice twice during their second year, as it would

not pay to leave such a heavy stand of alfalfa on the field at the advent of winter. They were cut only once (on July 20) and the second growth was left on the ground to furnish winter protection. Precipitation to the amount of 0.65 inch occurred during three cloudy days preceding the cutting and a copious rain fell a few days after the cutting. As a result, recovery was rapid and growth continued until well into the autumn. Indeed, the growth of over two months and a half remained on the ground.

The favorable conditions under which these plats entered the winter could scarcely be duplicated; they were in their second year, had enjoyed ample moisture for continued growth through the season, had been cut only once, and that in midseason, leaving a good stand to bind the snow. In spite of this the four varieties lost from 15 to 90 per cent of their stands, the loss varying greatly as we have seen on different parts of the plats. On June 10, 1909, a Turkestan strain from Tashkend, S. P. I. No. 14786, stood best of the four, followed closely by S. P. I. No. 13857 from Simbirsk, Russia. The loss in these strains based on careful estimates was 15 and 18 per cent, respectively. An irrigated strain from Utah (S. P. I. No. 12784) and one from Colorado (S. P. I. No. 12398) lost about 80 and 90 per cent, respectively. A slight portion of the loss in these two cases occurred in the mild winter of 1907–8, but most of it was due to the winter of 1908–9. The snow protection during the former was such that only the really tender kinds suffered even slightly. The other two strains, which were known to have a certain amount of hardiness, maintained full stands through the winter of 1907–8.

The nine other field plats were sown in May, 1908. This was an unusually favorable year for getting a stand of alfalfa. The nursery rows as well as the field plats shared in the beneficial conditions that prevailed, the latter in a higher degree than the former, as in dry or even ordinary years fields sown by the usual methods suffer considerable hindrance in growth because of a lack of moisture. This results in the autumn in an insufficient covering of vegetation to hold the snow that is necessary to furnish a winter protection to the plants.

April, 1908, had a little more than the normal rainfall. May, the month in which seeding was done, had a precipitation of 3.50 inches. This is more than an inch above normal and insured rapid germination and a good stand of young plants. June rainfall amounted to 4.30 inches, about $1\frac{1}{2}$ inches above normal. This enabled the plants to become firmly established and to make a fine growth throughout July, when $\frac{3}{4}$ inch less than the normal amount of rain fell.

These plats were clipped a few days after a heavy rain that fell July 24 and about ten days earlier than the experimental rows in the nursery. They began a prompt recovery which was no doubt gradu-

ally retarded by a hot dry spell that lasted until August 12. The hill and drill rows, which together contained an average of about seventy-five plants of each variety, were cut on August 5 in the midst of this dry time. As no rain fell until August 12 they were at some disadvantage in making a recovery. The field plats, on the other hand, had already begun growth and were forced to harden their tissues to a considerable extent. The presence of this hardened tissue was a factor of undoubted value in wintering over.

During the second half of August the rainfall was ample; the shortage for the whole month amounting to less than ½ inch as compared with the 16-year normal. September's rainfall (1.67 in.) exceeded the normal more than ½ inch, while October's precipitation (2.47 in.) was over 1½ inches more than this month usually receives. The rainfall of these two months had opposite effects on the row and field experiments, affecting the former unfavorably and the latter favorably. This seems paradoxical, but really is not. In the first place because of their sidehill location and hard uncultivated topsoil, as compared with the rows, the run-off was greater from the field plats than from the nursery.

The moist autumn benefited the field plats by enabling them to make a late growth through the autumn. This increased their snow-holding capacity. At the same time on account of the run-off and the far greater transpiration from a thick stand, the dangers attendant upon an excess of moisture in the soil during the winter were avoided.

In the nursery rows the opposite was true. There was a sufficient growth of plants in height, but the stand was too thin to hold much snow. The bare ground, the distance between the plants, and the cultivation resulted in a dangerous saturation of the soil. In the final analysis it was found that the presence of excess moisture in the soil and the absence of snow covering killed the plants in the rows, and the presence of snow covering and the absence of excess moisture enabled the plants in the field plats to live. It was dry enough in the plats to cause the formation of hard tissue without intercepting growth and wet enough in the rows to cause a sappy growth to continue until hard frosts stopped growth altogether.

The season and treatment were such that when winter came the plants in the field plats had made ample growth to hold the snow. Thickness of stand combined with height increased the snow-binding capacity. The thick stand, conducive to a greater transpiration, and the topography of the field, which promoted the run-off, prevented an excess of moisture in the soil when cold weather came. The opposite was true in the case of the rows. Furthermore, the field plats have a warmer, more protected situation, due to a southern slope and the location below the brow of a ridge. The rows are

located near the base of this ridge in such a way that they are rather more exposed to the prevailing winter winds which come from the northwest.

The row test is the severest to which alfalfa can be put in the area which Dickinson typifies, but as this general region, which includes large parts of North Dakota, South Dakota, and Montana, has a normal rainfall of less than 18 inches, row cultivation of alfalfa may prove to be the best farm practice. If this proves to be the case, the alfalfa suitable for this area must be able to bear this rigorous test successfully.

The rainfall for September and October, 1908 (4.14 inches), while unusual for Dickinson and all of the region west of the one hundredth meridian in the States just named, is normal in Minnesota, Wisconsin, and Michigan, and not infrequently occurs in eastern North and South Dakota and, as was the case in 1898 and 1908, in the western part of the Dakotas. The alfalfa for this region must be inured to this amount of autumn moisture followed by low temperatures with or without snow.

The winterkilling of varieties on the 1907 and 1908 field plats has already been discussed. It was found that there was a great diversity in loss on the thick and thin parts of the same plat. Where the stand was thin or inoculation poor, greater loss occurred. Ten of the varieties on the field plats were duplicated in the rows. In no case was the loss as great in the former as in the latter, but the comparative behavior in both cases was similar; that is to say, when ranged in series on the basis of winterkilling, the duplicate strains occupy a very similar relative position. The six strains that were shown to be the hardiest on the field plats rank in the following order: Montana Grimm, S. P. I. No. 21827; Nebraska Grimm, S. P. I. No. 21735; Turkestan, S. P. I. No. 20988; commercial sand lucern, S. P. I. No. 21217; Turkestan, S. P. I. No. 14786; Canadian, S. P. I. No. 21247.

In the rows where the test was severer, the ranking was as follows: North Dakota Grimm (row 52); Minnesota Grimm (row 51); Turkestan, S. P. I. No. 20988; Canadian, S. P. I. No. 21247; commercial sand lucern, S. P. I. No. 21217; Turkestan, S. P. I. No. 14786. Only the Canadian strain in the field plats fails to show the same relative strength. This is probably due to the unsubdued condition of the soil on this plat, which was new breaking, as well as to the original thinness of the stand, and not to any greater inherent weakness in the strain. Among the four weakest strains, in which the loss in the rows ranges from about 80 per cent up, the agreement is not so close.

From this it is apparent that we are dealing not so much with a difference in the hardiness of the varieties under comparison, but merely with differences in the amount of loss under tests of varying severity. Some of the factors that contributed to the greater loss in the nursery rows as compared with the thickly seeded plats may be summarized as follows:

(1) The 1907 field plats were cut between two rains, two weeks earlier than the rows; the 1908 plats were cut about ten days earlier than the rows and a few days after a good rain; the rows were cut August 5 in the midst of a hot dry spell that lasted over two weeks, the most protracted of an otherwise unusually favorable season for growing alfalfa.

(2) The field plats had a thick growth which by transpiration aided in exhausting excess moisture from the soil before winter came and later, together with weeds, furnished lodgment for a protective covering of snow that acted like a blanket in shielding the plants from cold.

(3) The field plats have a warmer, more protected situation, due to their location on a pronounced southern slope and below the brow of a ridge. The rows are located near the base of this ridge in such a way that they are more exposed to the prevailing winter winds which come from the northwest. This slope, by promoting the run-off, further aided in preventing the saturated condition of the soil, which undoubtedly acted disastrously on the nursery rows.

FURTHER OBSERVATIONS ON THE EFFECT OF AUTUMN MOISTURE.

In the preceding pages much emphasis has been placed on the injurious influence of autumn moisture on the wintering over of alfalfa. In order to determine whether similar losses have occurred in other experiments the alfalfa work of the North Dakota, South Dakota, and Minnesota stations has been studied especially. The winter of 1898–99 was one noted for its extremely low temperatures in the Great Plains region. At Brookings, S. Dak., the experiment station had a plat of the original importation of Turkestan alfalfa, S. P. I. No. 991, that lived through the winter successfully. Inasmuch as this same stock of seed suffered quite severely in the present row experiments at Dickinson the records were investigated to learn what caused the difference.

So far as temperature was concerned conditions were certainly more trying in the winter of 1898–99 than during the winter of 1908–9. According to Prof. E. C. Chilcott's records, during December, 1898, there were at Brookings thirteen days with temperatures below zero, the range being from $-2°$ to $-22°$ F. There was no snow during the month. January had fourteen days with minima below zero, the

absolute minimum temperature for the month being −27° F., which occurred on the 30th. The total snowfall for this month was 1.4 inches, which would have made a very light covering in any case, but because of winds was not very evenly distributed. A period of low temperatures began on January 26 and extended until February 13, culminating on February 9 in −41° F. On the 11th the mercury again fell to −38° F. Only 2.1 inches of snow fell during February; hence, the plat of Turkestan alfalfa had only such snow protection as was held by its own plant covering. Between February 5 and 12 the highest minimum temperature experienced was −25° F., while the highest of the maxima was 5° F. The spring weather was in all respects favorable, there being no alternate thawing and freezing worthy of mention.

The severe temperatures endured by S. P. I. No. 991 at Brookings in February, 1899, as compared with the same strain at Dickinson in January, 1909, makes it evident that there must have been some other difference in weather than temperature between the two winters to explain the extensive killing in one case and the living over in the other. An investigation of the precipitation record at Brookings shows that during September, 1898, 1.31 inches of rain fell between the 1st and the 15th; that only a little over 1 inch fell in October, all before the 15th, with snowfall on the 18th. It seems evident from this that the difference in autumn moisture and the consequent saturation of the soil was probably the determining factor at Brookings in the wintering over of No. 991. That autumn moisture interferes with plants becoming dormant agrees in a way with orchard practices in other sections, especially in irrigated areas. Orchardists desiring to harden their trees and force them into dormancy stop irrigating to produce the desired effect.

The experiences of the North Dakota Agricultural Experiment Station at Fargo tend to bear out this hypothesis. In 1901 a plat of Turkestan alfalfa was seeded on the station farm. This endured successfully the winter of 1901–2, but, according to Professor Shepperd, "failed to pass the winter of 1902–3 successfully, having been badly winterkilled. It was given the most trying conditions by having all of its stem growth mowed close to the ground just before cold weather began in the fall. A second plat of Turkestan seeded in the spring of 1902 which was left with a growth of stems a few inches high killed but little during the same winter." The record of rainfall at Fargo during the autumn of 1902 shows that over 5 inches of rain fell in October. This probably accounts largely for the greater amount of winterkilling in the plat from which no moisture was removed through transpiration than in the one left with some growth. Furthermore, the latter had the advantage of a plant covering to hold the snow.

Still other observations have been made which leave little doubt in the matter of winterkilling due to an excess of autumn moisture.[a] Prof. W. A. Wheeler in a paper presented before the Dry Farming Congress, at Billings, Mont., in October, 1909, called attention to the fact that the winter of 1905–6 resulted very disastrously to the nursery row experiments at the South Dakota substation at Highmore. Professor Wheeler commented especially on a northern-grown strain of common alfalfa which was almost wholly killed out. Only the Grimm alfalfa, acclimatized Turkestan alfalfa, and South Dakota No. 167—the so-called Baltic alfalfa—endured this winter successfully, and there was some killing in the two last named of these strains. The precipitation record for Highmore shows that almost 2 inches of rain fell in October, 1908, while the precipitation for November amounted to 1.29 inches. The alfalfas under experiment that suffered the worst were grown in rows, as at Dickinson; hence, the disastrous effect of this amount of rainfall was no doubt much greater than in thick stands.

This same winter (1905–6) is the only one in recent years which has injured seriously the stands of Grimm alfalfa in Carver County, Minnesota. Farmers have generally believed that the killing which took place that winter was due to the alternate thawing and freezing during February. A careful study of Minnesota winters for a period of years shows that many have had more severe conditions in this respect, hence it did not seem likely that this condition furnished a sufficient explanation. Again, the precipitation records were consulted and it was found that the September rainfall amounted to 4.15 inches, the October rainfall to 2.49 inches, while the precipitation for November which was practically all rain was almost $2\frac{1}{2}$ inches. It was noted that the killing was especially bad in the "draws," or depressions, which furnished drainage to the fields. Even where these "draws" or natural drainage ditches were on sidehills, as shown in Plate IV, figure 2, where water could not remain standing, the killing was severe. From this it seems that the condition was not one of an ice covering, but of saturation.

These examples have been selected to give further emphasis to the importance of autumn moisture. It has frequently been the case in irrigated sections that late irrigation has caused the killing out of alfalfa fields. However, it has generally been believed that the killing occurred only because the winters were open. The results at Brookings after the winter of 1898–99 indicate that open winters preceded by

[a] A brief but interesting discussion of the winterkilling of alfalfa under irrigation has been published recently by Prof. Samuel Fortier. See Farmers' Bulletin 373, U. S. Dept. of Agriculture, entitled "Irrigation of Alfalfa," 1909, pp. 41–42.

dry autumns, even when the temperatures are very severe, are not to be compared in injuriousness to winters preceded by moist autumns.

In the Milk River Valley of Montana ordinary alfalfa maintains its stands from eight to fifteen years, despite the fact that temperatures considerably lower than −40° F. occur rather frequently. Progressive thinning of the stand of course makes it necessary to reseed sooner or later. This is a region of scant autumn rainfall, which probably accounts for the success obtained in growing ordinary alfalfa. This same strain in Minnesota, North and South Dakota, Wisconsin, and many other Northern States succumbs in from two to five years, sometimes even sooner, though the temperatures generally are not nearly so low as those of northern Montana. All of these facts seem to indicate that moisture in the soil is one of the most important factors in determining whether or not alfalfa will winter over successfully.

DIVERSITY IN ALFALFA.

Alfalfa appears to be quite as diverse physiologically as it is botanically, and in the majority of cases botanical or morphological lines of descent seem to have no correlation with the physiological. That this should be the case is not surprising in a crop where the greatest freedom of interbreeding promoted by special adaptations for making insect visits effective is the rule. As a result of this condition strains that have by natural selection been rendered uniform with reference to physiological characters, such as cold resistance or drought resistance, may contain still the whole range of botanical diversity, so far as this is expressed in the external appearance of the plants.

Strains of Grimm alfalfa, for instance, contain lines of great mor phological diversity. Some are prostrate, some upright; some leaf profusely, others very sparingly; some incline to coarse woody stems, others to fine tender ones; some have small leaves, others large; some show only one of a number of flower colors, others are variegated, and so on through the whole range of possible differences. In the experiments thus far conducted none of these diverse elements have shown any observable differences in cold resistance. This suggests the possibility that the hardiness may be due to some histological character common to all the lines of descent.

Investigations of the physiology and histology of cold resistance have not yet produced much definite information, but it does not appear necessary to assume any one character as the basis of hardiness. Some lines may live through severe test conditions from one cause and some from another; in some it may be due to the faculty of becoming dormant at the proper time, in others to the habit of growing from deep-seated crowns, in still others to the power of

reestablishing a root system quickly when heaving or freezing has broken off the root.

As our knowledge of individual alfalfa plants becomes more intimate, some true correlations between the morphological and physiological characters may be found. At present we have few data along this line.

The belief has grown up recently that diversity or variegation in flower color is correlated with hardiness, and that drought resistance and cold resistance are also correlated. The evidence of the present investigations has been negative on both of these points. On the field plats the Kansas strain No. 19508, which undoubtedly came from Europe originally, has practically the same range of flower color as the Grimm strains. While one of the latter suffered no winterkilling and the other but little, the Kansas strain killed so badly that only about 20 per cent of a stand remained. The Grimm strains, as we have already seen, differed from one another in hardiness, though not in diversity of flower color. The two strains of commercial sand lucern S. P. I. Nos. 21217 and 21269 are far more variegated in color than any Grimm plants, still they proved less hardy on both the field plats and in the rows and also in experiments elsewhere in the Northwest. They themselves showed considerable difference in hardiness. On the other hand, strains like Wheeler's acclimatized Turkestan (S. Dak. No. 240), which has no variegation, proved hardier than any variety except the Grimm. This indicates that in the strains mentioned, at least, the factors producing cold endurance are independent of variegation or the factors producing it.

Similarly, it has been believed that drought resistance is correlated with hardiness. Some of the best drought-resistant varieties, however, proved in the row experiments to be the very weakest strains from a cold-resistance standpoint. The only dry-land form that showed any cold resistance worthy of comment came from Sextorp, Nebr., where in addition to a lack of sufficient rainfall low temperatures are often experienced.

Ordinary American alfalfa, which probably traces its history back to a single lot of seed taken from Spain to South America several centuries ago, also showed a range of more than 50 per cent in hardiness.

METHODS BY WHICH ALFALFAS BECOME HARDY.

A study of the whole group of alfalfas reveals the fact that the total range in variation in hardiness is much greater than in our common American strains. The best strain in the Dickinson experiment, a Grimm, lost less than 3 per cent, while twelve kinds killed out 100 per cent. Among the latter were four Arabian stocks that winterkilled completely in row and hill tests as far south as Stockton, Kans.,

where the winter of 1908–9 was milder than normal. This variation in hardiness of the different stocks is correlated positively with an indefinite minimum temperature or complex of climatic conditions of the country in which they have long been grown. In other words, the tenderest of the alfalfas come from the warmest regions and the hardier ones come from the colder regions.

The first method of securing a hardy alfalfa is illustrated in the case of Grimm alfalfa, South Dakota Nos. 240 (originally from Turkestan) and 167, and by those strains of ordinary American alfalfa that show more than average hardiness.

The evidence is good and fairly conclusive that the alfalfa which Wendelin Grimm brought over from Germany in 1857 was neither better nor worse than the average central European alfalfa. It also contained many lines, some of which were hardier than others. Mr. Grimm did not start a nursery and propagate one plant that showed itself superior to the others. He sowed the whole lot of seed and harvested what he could. This was done repeatedly and as the years passed by nature weeded out the tender lines, while the hardier ones persisted.

This process no doubt gradually brought about a profound change in the stock as a whole. It is, however, not necessary to suppose that the lines which have persisted in the Grimm alfalfa are any different than they were in the original seed brought over fifty years ago. They are simply more abundantly represented in the population making up the strain. On the other hand, it may be that the Grimm stocks used in our experiments do possess lines hardier than any contained in the foundation stock. These could have arisen readily by mutation, a recombination of characters,[a] or otherwise since the date of the introduction of the strain. This assumption is not necessary, as all the central European alfalfas that underwent the severest test of the row and hill experiment possessed some hardy lines which could be made the basis of further propagation.

Another method may be used, but the ultimate principles involved are the same. As already pointed out, any stock of alfalfa seed, even when grown in a restricted area for a long time, is made up of a number of lines or families which vary both morphologically and physiologically and which breed more or less true. In our study of hardiness the majority of strains or regional varieties possessed some plants which lived through the northwestern winter. The plants that lived through were representatives of the hardier lines. Now evidently a

[a] Methods by which recombinations produce a change in cross-fertilized plants are discussed by Prof. W. J. Spillman. See "Application of Some of the Principles of Heredity to Plant Breeding," Bulletin 165, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, pp. 36–43.

simple method of securing cold endurance is to select any representative hardy plant and increase it. By this method of breeding we are led to the establishment of a pure or nearly pure strain.

The Minnesota Agricultural Experiment Station and Prof. W. A. Wheeler, of South Dakota, have followed this method, basing their pure strains largely on selected Grimm plants. During the past season Professor Wheeler produced as much as 200 pounds of seed that traces its ancestry to a single plant. This method is also being followed by Mr. A. C. Dillman, of the Office of Alkali and Drought Resistant Plant Breeding Investigations, in his work at Bellefourche, S. Dak.

In this method the singling out of the representative plant is the important thing. It naturally presupposes some antecedent method of getting rid of the weaklings and hence applies not so much to the establishment of a hardy race as to the isolation of a pure or uniform race from a mixture of predetermined hardiness. The advantages and disadvantages of this method are little known. Observations on other crops indicate that there is considerable danger in a too narrow restriction of lines of descent.[a]

The length of time required to produce from a mixed stock by unconscious mass selection[b] an approximately pure race, so far as cold resistance is concerned, is uncertain. It will evidently depend almost wholly on two factors, namely, the abundance of hardy individuals in the original stock and the frequency with which test winters occur.

South Dakota No. 240 (see pp. 51–55) is an example of the establishment of a very hardy and nearly pure strain from a mixed strain having a lesser degree of hardiness. The new hardy strain was developed immediately, without the necessity of intercrossing or long-continued selection. The experience with this strain and observations on others indicate that the time required need not be long. The original seeding in the case of No. 240 was made in 1899; the seed used in the experiment was harvested in 1906. A study of the records for Highmore, S. Dak., and neighboring points shows that test weather conditions prevailed several times during the interim.[c]

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[a] Our knowledge of the amount of cross-pollination that takes place when alfalfa plants are left exposed is very deficient. If we wish to select a line and propagate it pure, the prevention of cross-pollination is necessary. If the plant selected is an F_1 cross with regard to any character, then it is obvious that the selection and self-pollination of several individual plants may be necessary in the next generation before a really pure strain is obtained.

[b] Cook, O. F. The Superiority of Line Breeding over Narrow Breeding. Bulletin 146, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, pp. 28–29.

[c] The following minimum temperatures at Highmore, S. Dak., indicate the nature of the test that alfalfa endures in this locality: 1904, −27° F.; 1905, −36° F.; 1906, −31° F.; 1907, −27° F.

The seed production of No. 240 has been uniformly poor. Most stocks of Turkestan alfalfa share in this weakness. In some years the plats appear not to have been cut at all; in 1904 only the first crop was removed. In consequence of this, the surviving plants undoubtedly produced seed which was not harvested, but fell on the ground, thus bringing about natural reseeding. In this case seven years of unconscious mass selection toward cold resistance resulted in an unusually hardy strain. The Grimm variety is the product of fifty years of similar selection in the Northwest.

The term "selective acclimatization" may be applied to this process of change whereby hardy lines or races in a crop plant are accentuated in later generations by the elimination from year to year of unfit lines. The versatility of a race produced in this way in meeting new conditions in other areas than the one in which it was developed will probably hinge largely on the range of selective factors to which it has been subjected in its previous history.

Hybridization between alfalfa and its wild relatives has been suggested as an immediate method of securing hardiness.[a] Its use, however, would not dispose of the necessity of selection both before and after the making of the crosses. Antecedent selection will be required for determining the hardiness of the chosen parents of both the wild and cultivated stocks, while the subsequent selection will be essential for eliminating the nonhardy by-products of crossing and isolating the lines of high forage and seed value.

CONCLUSION.

The investigations that form the basis of the present paper have been under way at Dickinson, N. Dak., for nearly four years. At other places in the Northwest they have continued a year longer. The observations recorded show that the employment of good tillage, the use of a suitable strain of seed, and the character of the winter weather are the controlling factors in successful alfalfa production in the Northwest when soils of average fertility are used.

With reference to tillage it may be said that the previous cropping and treatment of the soil and its thorough preparation are of primary importance. Inoculation, irrespective of the manner in which it is secured, determines success or failure, even though all other conditions are satisfied.

It was found that by varying the time of cutting in order to leave considerable growth on the field in the autumn, even the strains of inferior hardiness endured, though the conditions were severe. This result appeared to be due to the exhaustion of moisture from the

[a] For an extended discussion of this point of view, see Westgate, J. M., "Variegated Alfalfa," Bulletin 169, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910.

soil in the autumn and to a plant covering which held a protective blanket of snow over the alfalfa crowns during severe weather. Thinness of stand resulted in a high percentage of winterkilling in all except the hardiest varieties. Farmers who are unable to secure sufficient seed of hardy strains for acreage plantings may find it profitable to use less hardy strains, planning to leave the late summer and early fall growth standing to hold the snow.

Thoroughness in preparing the soil promotes inoculation, which is essential to satisfactory yields. Lack of attention to this point has led in thousands of cases to the plowing up of alfalfa stands in the Northwest that would otherwise have been successful. Inoculation is just as necessary for hardy as for nonhardy strains of seed.

Present experiments show that undoubtedly the most important cause of failure in actual practice has been the use of seed from regions that in the nature of things can not produce adapted seed. In practically all of the present alfalfa-growing areas of the United States, ordinary American alfalfa and commercial importations of seed from abroad have proved to be entirely satisfactory or else so easily adaptable to conditions as to become satisfactory after one or two generations of seed have been produced. This is particularly true where alfalfa is grown under irrigation. Even as far north as the Yellowstone and Milk River valleys of Montana ordinary Utah seed has given satisfactory results, except in unusual years. In the more humid parts of the cold North and Northwest this has not proved the case. After a severe winter in these sections fields of nonhardy forms of alfalfa show only the dry crowns of dead plants, with here and there a growing plant. The profusion of the latter depends wholly upon the degree of winter resistance of the particular strain used, that is, upon the percentage of cold-resistant individuals included in its population.

Our knowledge is still meager as to what quality or qualities produce hardiness in different races of alfalfa. The importance of ability to become dormant in spite of weather calculated to force continued growth has been pointed out. At least two other characteristics of the plants themselves have been observed that are believed to be of importance. The Mongolian alfalfa which proved to be the hardiest under the severe test at Dickinson of any of the newly imported strains was found both there and at Stockton, Kans., to have crowns more deeply set in the soil than other varieties. It seems likely that this adaptation, if it may be called an adaptation, is of importance in giving the tenderest part of the plant the needed protection.

Another condition has been noted, especially in Grimm alfalfa. On taking up the crowns in old stands it has been observed that at some previous time the taproot has been completely broken off from

4 to 8 inches below the surface.[a] Living plants in such cases have developed new roots laterally to take the place of the broken ones. This condition has suggested the possibility that the long endurance of stands of the Grimm strain may be due in some measure to a capacity for putting out new roots and reestablishing itself after the taproot has been broken. The data collected on this point do not yet justify anything like positive statements, but it is mentioned in this connection to stimulate growers and breeders to make note of similar conditions.

With reference to weather conditions, which because of their importance have been discussed rather fully in the present paper, the following appeared to be the most destructive to alfalfa stands under the conditions studied:

(1) A lack of sufficient snowfall or the exposure of plants, due to drifting. The latter condition can often be remedied by making the last cutting of hay early enough so that the field will have 8 or 10 inches of plant growth to bind the snow.

(2) Successive thawing and freezing, which may kill the plants outright by rupturing their tissues or kill them indirectly by heaving the soil, thus breaking the main roots and stripping off the lateral roots. The crown of a plant killed in this way can be drawn from the ground without effort, and in the spring it usually dries out before it can reestablish itself.

(3) An excess of moisture in the autumn which by preventing the plants from hardening up their tissues results in their being in a more or less tender and succulent condition when winter weather sets in. Alternate thawing and freezing are especially deadly when a wet autumn or a late irrigation leaves a high percentage of moisture in the soil.

Dry winters have been supposed to be highly injurious to alfalfa, but the writers' observations indicate that it is only the dry winters which are preceded by moist autumns that do the greatest injury. A dry fall furnishes more favorable conditions for wintering over by producing more perfect dormancy. In the well-recognized alfalfa-growing areas of the United States winterkilling has never occasioned excessive losses.

Observations elsewhere than at Dickinson have shown at least two other important external conditions that conduce to winterkilling, namely, sleet or a coat of ice which is usually an accompaniment of alternate thawing and freezing, and severe pasturing, whether by cattle, sheep, or hogs, especially if it is carried late into the autumn. In the case of ice formation it seems probable that the plants are injured both by a rupture of the tissues and through being deprived of the necessary aeration.

[a] Mr. T. H. Kearney calls attention to the fact that ordinary alfalfa in Arizona does this when the taproot has been destroyed by Ozonium. This disease has not been found in Carver County, Minnesota.

No doubt many other factors in addition to those discussed in this bulletin are concerned in the rapid depreciation of alfalfa stands in cold climates. It is hoped that the present investigations may contribute to a fuller knowledge of the subject and assist in the establishment of an alfalfa industry in the Northwest comparable to that which has grown up farther west and in the Southwest within the past fifty years.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. (*Frontispiece.*) Fig. 1.—Experimental plats of alfalfa in hills and drill rows at Dickinson, N. Dak., on October 1, 1908. Each row was sown to a different strain in the spring of 1908, 68 kinds in all, and on the date the photograph used for this illustration was taken practically every one had a full stand. Fig. 2.—The same experimental plats at Dickinson, N. Dak., on June 10, 1909, showing the great diversity in the winter resistance of alfalfa from different parts of the world. The statistics of winterkilling for the section in the immediate foreground, rows 35 to 68, counting from right to left along the white stakes in the middle of the picture, are shown in the second part of Table XIII. Those for rows 1 to 34, comprising the section between the first and second complete lines of stakes, are presented in the first half of Table XIII.

PLATE II. Fig 1.—Experimental plats showing the importance of a snow covering. The small patch of red clover in the foreground stands in the meager shelter of an old back furrow. This furrow, which is only slightly higher than the soil around it, held a few inches of drifting snow over the plants and preserved them from injury, while the remainder of the plat, which is only a few hundred feet from the alfalfa nursery, killed out completely. Fig. 2.—Experimental plats at Stockton, Kans., showing the winterkilling of North African and Arabian alfalfa in the mild winter of 1908–9. The middle row is Kebilli Oasis alfalfa, No. 12846, secured by Mr. T. H. Kearney from Tunis. At Dickinson, N. Dak., this strain killed out 100 per cent. (See row 20, Table XIII.) The row at the right of this, showing a few plants, is from Tripoli. Two rows to the right of the Tripolitan strain and at the left of the Tunisian are Arabian alfalfa, the tenderest variety known. Not a living plant at Stockton remained in any of the Arabian rows in the spring. These rows are identical with Nos. 6, 7, 8, and 9, Table XIII, Dickinson experiments.

PLATE III. Fig. 1.—Experimental plats showing seven rows of European alfalfa after the winter of 1908–9 at Dickinson, N. Dak. The four rows to the left of the arrow nearest the middle of the picture, Table XIII, rows 57 to 60, inclusive, are the so-called commercial or false sand lucern from France and Germany. Row 61 is Italian alfalfa and row 62 Provence alfalfa grown in Germany. Row 63, immediately to the right of the arrow nearest the margin, is another sample of commercial sand lucern. The two rows to the right of the middle arrow, rows 56 and 55, Table XIII, are Utah dry-land alfalfa. Next is South Dakota No. 167, row 54, the so-called Baltic alfalfa, while between this and the two rows of Grimm alfalfa, at the right, is a row of Brott's Nebraska dry-land alfalfa. Fig. 2.—Experimental plats showing three rows of Mongolian, the hardiest newly imported alfalfa included in the experiment, Dickinson, N. Dak., August, 1909. (See rows 2, 3, and 4, Table XIII.)

PLATE IV. Fig. 1.—Experimental plats showing the winterkilling of North American alfalfa and some other strains at Dickinson, N. Dak. Photographed June 10, 1909. The row indicated by the arrow, row 47, Table XIII, is Colorado alfalfa, which was included in the field, plat, and row experiments. In order, the rows to the left of the arrow are as follows: No. 48, Kansas; 49, Chinook, Mont.; 50, Clearwater, Nebr.; 51, Minnesota Grimm; 52, North Dakota Grimm. To the left of the arrow are the following: No. 46, first quality commercial, of European origin, with variegated flower color; 45 and 44, Mexico; 43 and 42, Canada; 41, Billings, Mont.; 40, Wheeler's acclimatized Turkestan. Fig. 2.—A field of Grimm alfalfa in Carver County, Minnesota, showing the nature of the severe winterkilling of 1905–6. Although this field is located on a sidehill, so that no water could remain standing on it, considerable winterkilling took place in the "draws" or natural drainage courses of the field where the soil had become oversaturated by autumn moisture. Photographed in September, 1909.

FIG. 1.—EXPERIMENTAL PLATS AT DICKINSON, N. DAK., JUNE 12, 1909, SHOWING THE IMPORTANCE OF A SNOW COVERING.

The patch of red clover in the foreground was preserved by a light covering; the remainder of the field was killed out.

FIG. 2.—EXPERIMENTAL PLATS AT STOCKTON, KANS., SHOWING THE WINTERKILLING OF NORTH AFRICAN AND ARABIAN ALFALFAS DURING THE MILD WINTER OF 1908-9.

FIG. 1.—EXPERIMENTAL PLATS OF EUROPEAN ALFALFAS AFTER THE WINTER OF 1908-9 AT DICKINSON, N. DAK.

The seven rows between the arrows (Nos. 57 to 63, counting from right to left) are from Europe.

FIG. 2.—EXPERIMENTAL PLATS AT DICKINSON, N. DAK., AUGUST, 1909, SHOWING THREE ROWS OF MONGOLIAN ALFALFA, THE HARDIEST FOREIGN-GROWN STRAIN.

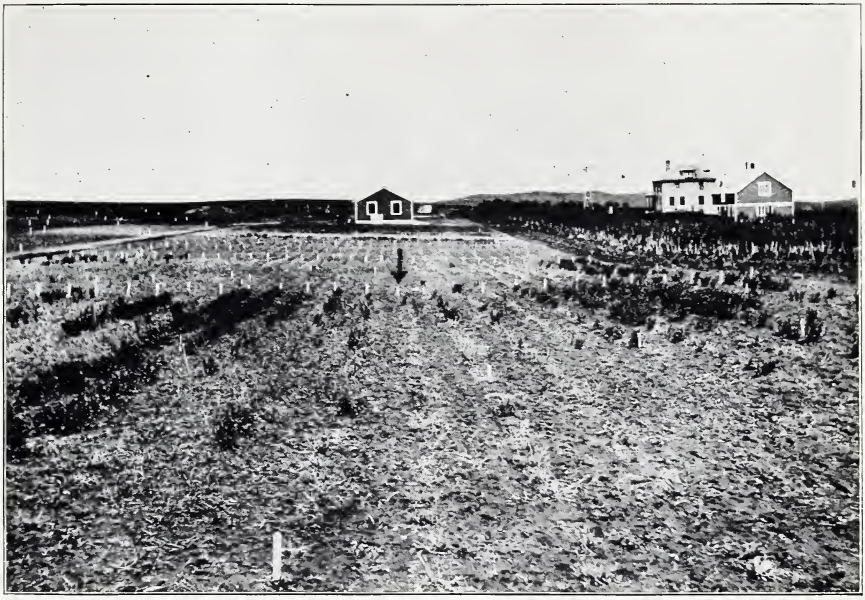

FIG. 1.—EXPERIMENTAL PLATS AT DICKINSON, N. DAK., SHOWING THE WINTERKILLING OF NORTH AMERICAN STRAINS OF ALFALFA.

The rows are numbered from right to left, the arrow indicating No. 47.

FIG. 2.—A FIELD OF GRIMM ALFALFA IN CARVER COUNTY, MINNESOTA, SHOWING THE WINTERKILLING IN 1905-6 IN THE "DRAWS" OR NATURAL DRAINAGE COURSES OF THE FIELD.

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